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## The Data Distribution Satellite System

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Ronald C. Bruno and Aaron Weinberg  
*Stanford Telecommunications*  
*Reston, Virginia*

September 1991

Prepared for  
Lewis Research Center  
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National Aeronautics and  
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## **SECTION 1**

### **EXECUTIVE SUMMARY**

The Data Distribution Satellite System (DDSS) described in this report will be capable of providing the space research community with inexpensive and easy access to space payloads and space data. Furthermore, the DDSS is shown to be a natural outgrowth of advances and evolution in both NASA's Space Network and in commercial satellite communications. The roadmap and timescale for this evolution is described in this report along with key demonstrations, proof-of-concept models, and required technology development that will support the projected system evolution toward the DDSS.

## **1.1 STUDY GOALS**

The key goals of this study are outlined in Exhibit 1-1. The first goal is to define how a DDSS, in concert with the follow on to Advanced TDRSS, an Advanced Space Data Acquisition and Communications System (ASDACS), can support NASAs space communication requirements in three areas. These areas are:

- Direct distribution of space data
- Easy and interactive communications with space payloads
- Networking among the community of space scientists and major processing and archiving facilities.

The DDSS and ASDACS are assumed to be products of a natural evolution in NASA's Space Network (SN). Thus, the second important goal of the study is to show how the orderly transition from ATDRSS to the ASDACS/DDSS may be accomplished. The current plan is for the ATDRSS lifetime to extend from 1997 to 2012 which thus defines the applicable timeframe for the transition activities. Finally, the third study goal is to develop and describe key demonstrations and proof-of-concept models that will serve as an R&D basis for establishing achievable ASDACS/DDSS performance goals and designs.

- DEFINE A DATA DISTRIBUTION SATELLITE SYSTEM (DDSS) AND AN ADVANCED SPACE DATA ACQUISITION AND COMMUNICATIONS SYSTEM (ASDACS) THAT SUPPORT THE YEAR 2010 SCENARIO FOR
  - DIRECT SPACE DATA DISTRIBUTION TO PRINCIPAL AND OTHER INVESTIGATORS
  - INEXPENSIVE, USER FRIENDLY AND INTERACTIVE COMMUNICATIONS WITH SPACE PAYLOADS
  - NETWORKING AMONG SPACE SCIENCE PEER INVESTIGATORS AND MAJOR PROCESSING AND ARCHIVING FACILITIES
- DEFINE THE STEPS THAT MUST BE TAKEN TO PROMOTE AN ORDERLY TRANSITION TO THE DDSS AND ASDACS ARCHITECTURE
- DESCRIBE PROOF OF CONCEPT MODELS THAT WILL DEMONSTRATE IMPORTANT FUNCTIONAL AND PERFORMANCE CAPABILITIES OF THE CRITICAL TECHNOLOGIES THAT SUPPORT THE DDSS

Exhibit 1-1: Data Distribution Satellite System Study Goals

## 1.2 DDSS TIMEFRAME

Exhibit 1-2 illustrates the 25 year time period from 1990 to 2015, in which TDRSS is replaced by ATDRSS, and ATDRSS gives way to the ASDACS/DDSS. Since ATDRSS is planned to last out to 2012, the time frame for an operational DDSS begins as early as 2010. However, to ensure an orderly transition from ATDRSS, a number of DDSS-related activities are appropriate much earlier in the ATDRSS time frame. These include the initiation of a demonstration DDSS as early as 2005, as well as more limited ground and flight demonstrations beginning in 1995. Proof-of-Concept (POC) model development could begin as early as 1992.

The planned Future Service Growth (FSG) capability of the ATDRSS is of particular importance in such demonstrations. The FSG is an allocation of ATDRSS real estate, mass and power for a payload that will support evolution and growth in ATDRSS services. As will be shown in this study, the FSG can play a pivotal role in the transition from the ATDRSS to the ASDACS timeframe. This transition could consist of 3 stages as follows:

- In the first stage starting in 1997, the FSG could be used to demonstrate a new ATDRSS capability as a prelude to a second operational stage.
- In the second operational stage starting about 2000, the FSG payload will support the new ATDRSS capability as part of normal operations.
- Finally, in the third stage starting as early as 2005, a demonstration DDSS satellite could be launched and provide much expanded capabilities and services. Here too, the FSG would play a key role such as providing the interface for linking an ATDRS\* with the demonstration satellite via an intersatellite link.

With all three stages initiated, the path would be paved for complete transition to the operational ASDACS/DDSS architecture because, both the spacecraft technology and operational aspects would have been thoroughly explored.

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\* ATDRSS - The system.  
ATDRS - A single relay satellite of the system.

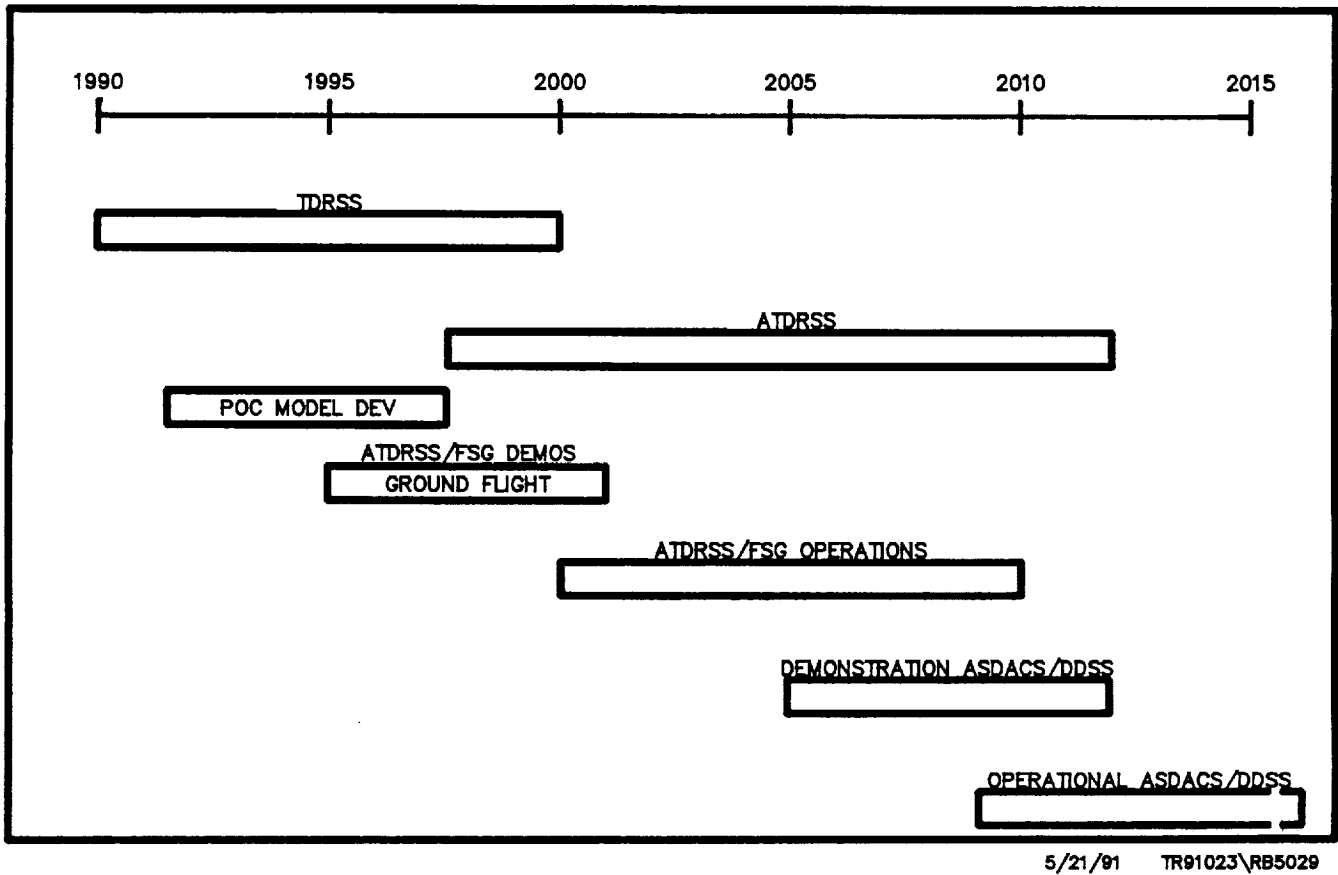


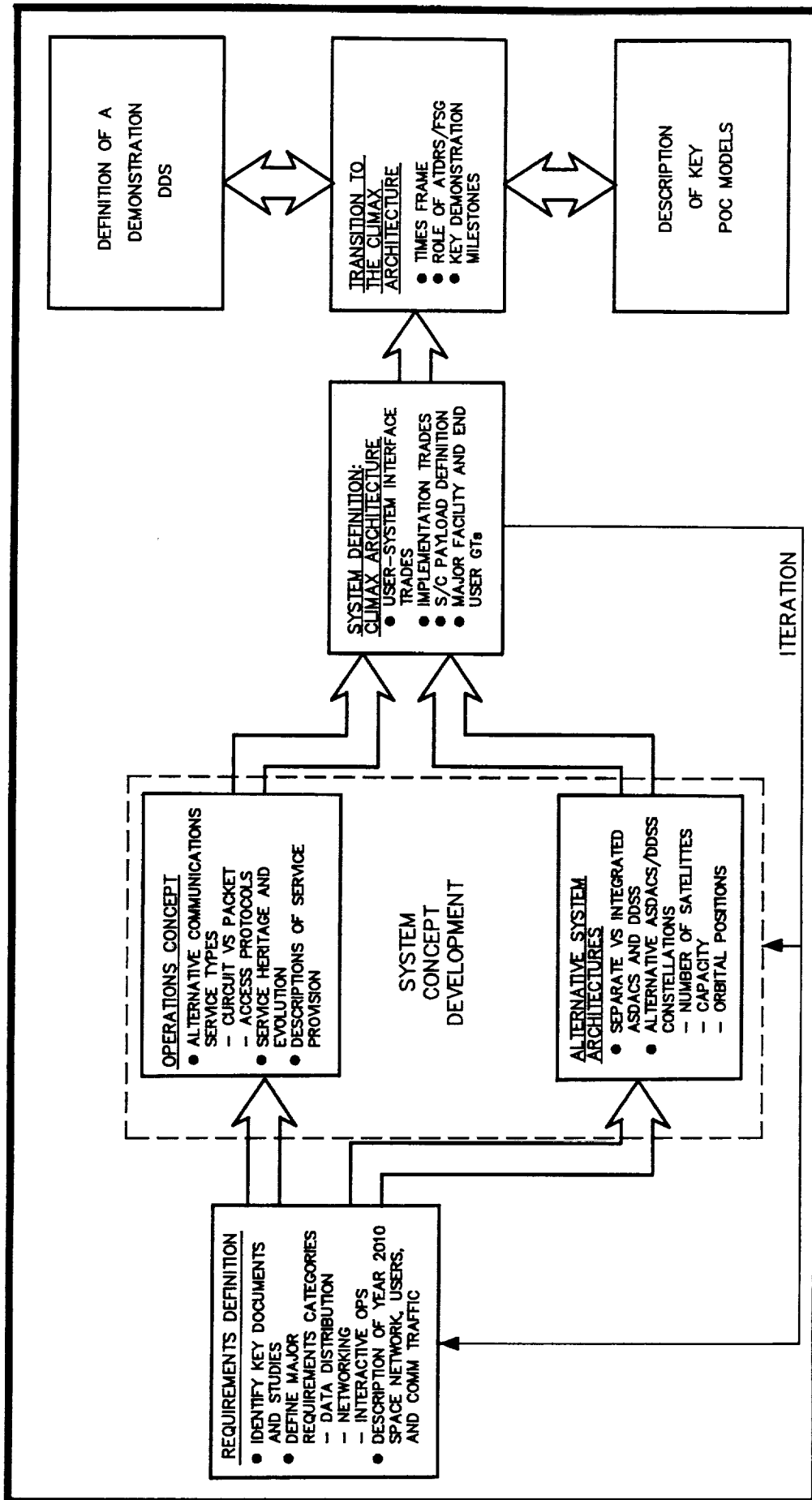
Exhibit 1-2: Timeframes for Evolution from TDRSS to ATRSS and Beyond

### 1.3 DDSS STUDY WORK FLOW

Exhibit 1-3 illustrates the work flow for this study. The projected requirements for the DDSS are developed at the outset from key NASA documents and studies. These include the most recent ATDRSS Mission Model as well as planning documents for data handling and distribution in the various science disciplines. The chief driver in this latter arena is the earth science area embodied in the Earth Observation System (EoS).

The developed requirements form the basis for parallel efforts aimed at exploring the DDSS operations concept and system architecture. The operations concept is strongly influenced by ATDRSS heritage as well as evolving concepts for advanced commercial satellite communications. In the system architecture definition, two alternative classes of architectures are explored: one where ASDACS and DDSS functions are integrated into the same spacecraft, and one where the ASDACS and DDSS functions are allocated to distinct spacecraft.

The work on operations concept and system architecture then flows into system definition. In this area, the major performance envelopes of the ASDACS, DDSS, and the user community are derived and reference implementations are developed. The culmination of this work is the definition of a climax DDSS and ASDACS system that meets all of the projected requirements developed at the outset. These results then feed back into requirements to determine the sensitivity of the DDSS design to modest changes in the initial requirements. This iteration is important for defining a demonstration DDS to support the smooth transition from ATDRSS to the ASDACS/DDSS. The output of transition considerations is a roadmap for system evolution versus time which includes the definition of key demonstration objectives and milestones for POC models, flight demonstrations, and a demonstration Data Distribution Satellite.



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Exhibit 1-3: DDSS Study Work Flow

## 1.4 KEY STUDY RESULTS AND CONCLUSIONS

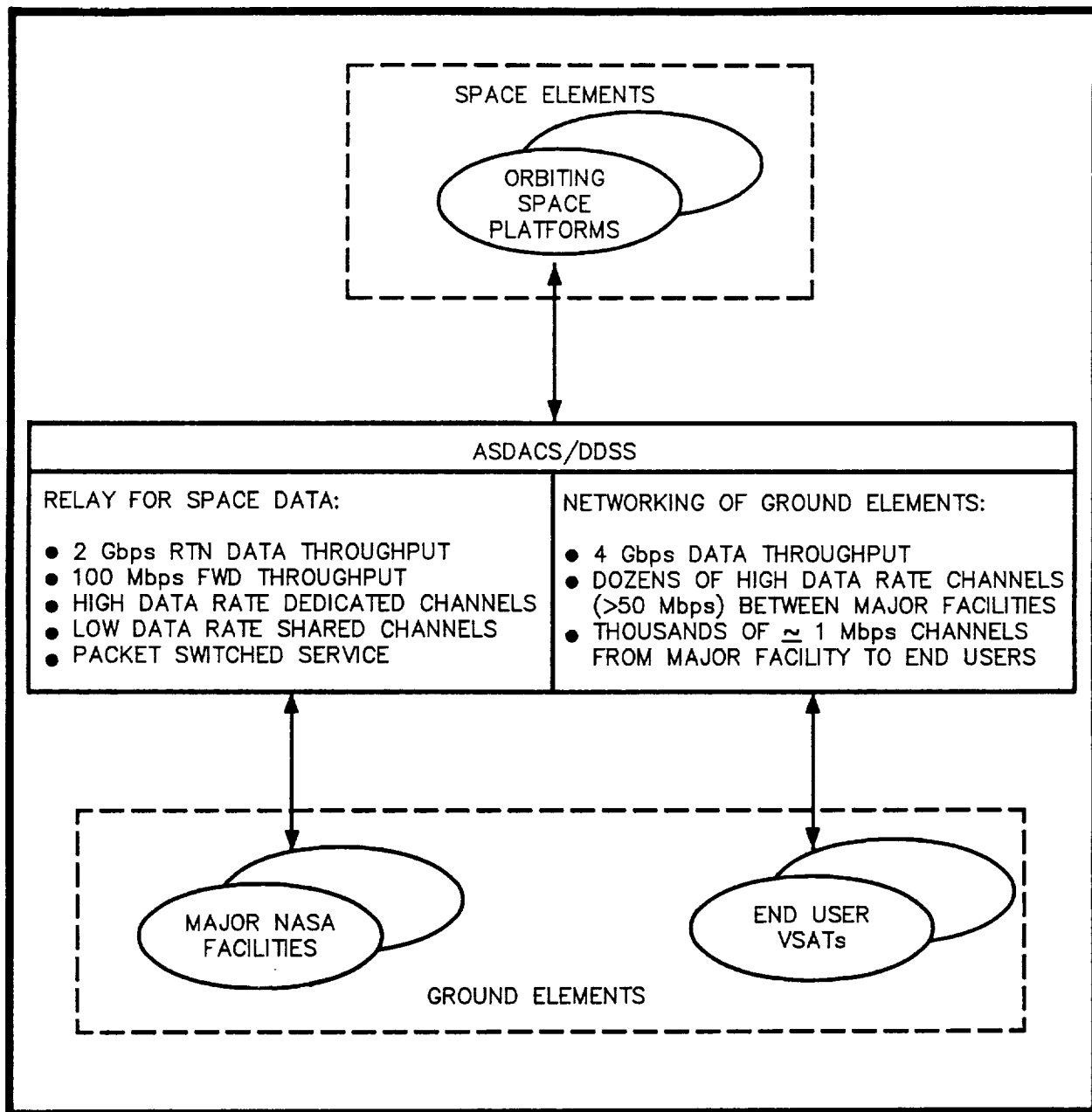
The key outputs of this DDSS study are:

- The identification of baseline communications requirements for direct distribution of space data, interactive space operations, and networking.
- The definition and evaluation of two alternative DDSS/ASDACS architectures and their corresponding communications payloads.
  - CONUS Gateway Architecture
  - Global Network Architecture
- A description of scenarios for orderly transition from ATDRSS to the CONUS Gateway architecture
- Descriptions of demonstrations and Proof-of-Concept (POC) models supporting DDS development and transition to the CONUS Gateway architecture
- Definition of a demonstration DDS applicable to the ATDRSS timeframe

### 1.4.1 Requirements

Exhibit 1-4 summarizes the potential system requirements for communications with orbiting space platforms, and for networking of NASA's Major Facilities and End Users of space data. Key features of the projected requirements are a high data throughput rate. The chief driver for this is the 4 Gbps throughput for networking Major Facilities (archives, processing centers, and supercomputer centers) and End Users (users of space data not in major facilities; interface is assumed to be via VSATs). The 4 Gbps is made up of dozens of high data rate two-way channels ( $\geq$  or 50 Mbps) connecting major facilities and perhaps thousands of lower data rate one-way channels ( $\approx$  1 Mbps) from Major Facilities to End Users. The networking throughput also incorporates thousands of low data rate connections (16-128 Kbps) between thousands of End Users for data, voice, and videoconferencing. The other major driver for system throughput is the return space data channels. ATDRSS will provide as many as 8 single access channels that support high data rate return services at up to 650 Mbps. The 2 Gbps peak throughput projected for return space data is consistent with the simultaneous use of as many as 3 return channels at 650 Mbps or 6 channels at 300 Mbps.





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Exhibit 1-4: Projected System Requirements for the ASDACS/DDSS

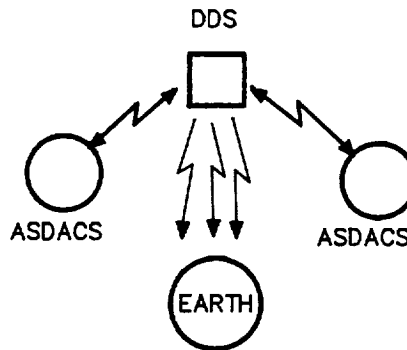
#### **1.4.2 Alternative Architectures**

Exhibit 1-5 illustrates the two alternative classes of ASDACS/DDSS architectures explored in this study. The CONUS Gateway Architecture assumes separate DDS and ASDACS satellites that are "connected" via RF or optical crosslinks. The DDS would be placed directly over CONUS and the two ASDACS relays would be positioned at locations with wider separations than the E and W locations envisioned for ATDRSS. In this manner, the CONUS Gateway Architecture would eliminate the zone of exclusion (ZOE). In the Global Network Architecture, the ASDACS and DDS functions are integrated into a common satellite. The Global Network constellation would be made up of 2-4 such satellites connected via crosslinks. Placement of the satellites would be such as to eliminate the ATDRSS ZOE and to provide a Global Network connecting major facilities and end users located in all key nations active in space.

For both the CONUS Gateway and Global Network Architectures, communications payloads were defined that meet the projected system requirements. The payloads were described at the block diagram level for major components, and weight and power estimates were generated with the components identified in the diagrams serving as the starting point. While both payloads were large, the payload for the Global Network Architecture was especially so, given that it must support the functionality of both the ASDACS and the DDS. The Global Network Architecture also involves significantly more operational complexity and uncertainty because it is essentially an international system providing service to all nations active in space. Finally, the Global Network Architecture does not lend itself to a transition from ATDRSS. For these reasons, only the CONUS Gateway Architecture was chosen for complete description.

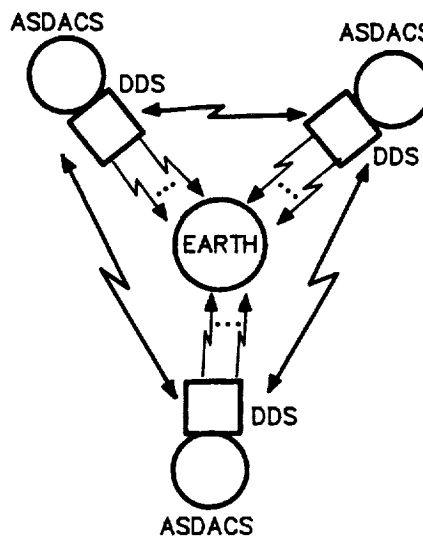
### CONUS GATEWAY ARCHITECTURE

- SEPARATE DDS AND ASDACS SATELLITES
- DDS POSITIONED OVER CONUS
- TWO OR MORE ASDACS WITH XLINKS TO DDS
- ASDACS CONNECTIVITY TO GROUND VIA DDS
- CENTRALIZED NETWORK CONTROL AND TT&C



### GLOBAL NETWORK ARCHITECTURE

- INTEGRATED DDS AND ASDACS SATELLITES
- TWO OR MORE ASDACS/DDS POSITIONED IN VIEW OF KEY REGIONS: CONUS, EUROPE, JAPAN
- XLINKS PROVIDE GLOBAL CONNECTIVITY
- DISTRIBUTED NETWORK CONTROL AND TT&C



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Exhibit 1-5: Alternative Architectures

### 1.4.3 Transition Issues

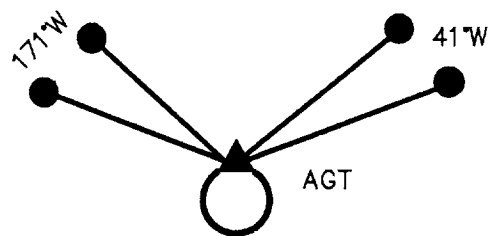
The transition from the ATDRSS to the CONUS Gateway Architecture involves the major changes in a number of areas. These include:

- Changeover to a new system architecture and orbital constellation
- The development of new communications payloads and satellites
- The insertion of new technologies into the communications payloads
- The introduction of new operations concepts concerning service provision, assurance and scheduling

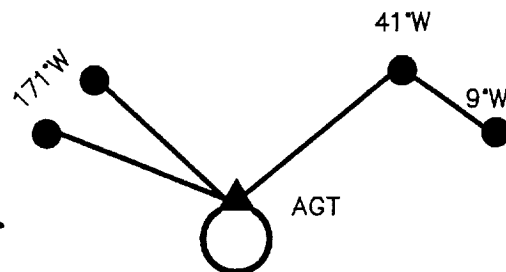
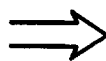
The baseline ATDRSS is comprised of four operational satellites which all have line-of-sight to the ATDRSS ground terminals at the White Sands complex as indicated in Exhibit 1-6. In this architecture, all SGL connections to the satellites are via the White Sands complex. In contrast, in the CONUS Gateway architecture there are many SGL connections to the Major Facilities and thousands of connections to VSATs widely distributed over CONUS. Furthermore, neither of the ASDACS satellites have line of sight to White Sands, but are instead connected to White Sands and other CONUS locations via crosslinks.

With the introduction of so many new features, it will be important to plan the transition so that the new features can be demonstrated prior to operations, and these features can be introduced in a gradual manner. Exhibit 1-6 illustrates potential route for the transition of NASA's space network from TDRSS, through ATDRSS, and finally to the DDSS/ASDACS system. Within this timeline, it is seen that the ATDRSS Future Service Growth (FSG) module [12] can play a key role in supporting an orderly transition from the ATDRSS to its follow-on (i.e. the DDSS CONUS Gateway architecture). The ATDRSS/FSG is a reserved allocation of spacecraft resources (weight, power, size, view angles) that will host a payload yet to be defined. The objective of the FSG is to support a modest growth in the services offered by ATDRSS. Possible payload options under consideration include a crosslink capability as well as a direct data distribution capability.

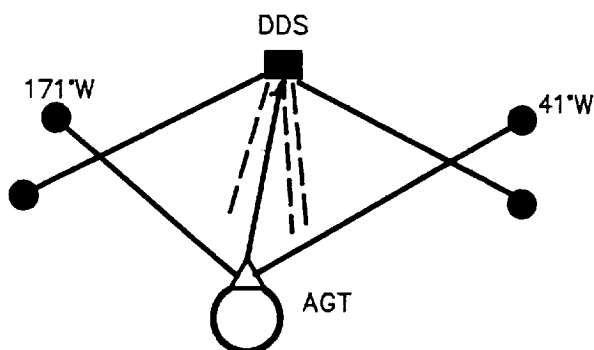
The opportunities for the first flight demonstrations utilizing the ATDRSS/FSG will occur from the late 1990's to the early 2000's. If successful, similar payloads on the FSG will support service enhancements throughout the ATDRSS era, from the early 2000's to beyond 2010. Finally, starting about 2005, the launch of a demonstration satellite with most of the capabilities of the DDS in the CONUS Gateway architecture would be feasible. Each of these activities are phased such that the preceding activity supports the definition of the follow-on. Thus, successful demonstration of an FSG capability leads to operational support of that capability. This operational capability can then be greatly enhanced by the introduction of the demonstration DDS which in concert with a crosslink to the ATDRSS/FSG, can close the ATDRSS coverage zone of exclusion and offer direct data distribution services. Finally, the demonstration DDS supports a gradual transition to the DDSS/ASDACS climax architecture as is shown in Exhibit 1-6.



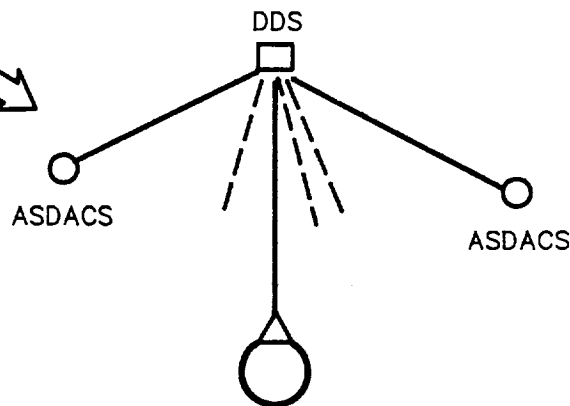
- BASELINE ATRSS ARCHITECTURE



- ATRSS/FSG DEMO
- EVOLUTION TO OPS
- SHORT X-LINK SUPPORTED BY FSG CLOSES ZOE
- LONGER X-LINK VALIDATES DEMONSTRATION DDS



- TRANSITION ARCHITECTURE
- DEMONSTRATION DDS DOES ON-BOARD PROCESSING AND PACKET SWITCHED DIRECT DISTRIBUTION OF DATA
- X-LINKS TO DDS SUPPORTED BY FSG CLOSES ZOE
- ALSO SUPPORTS NETWORKING AMONG MAJOR FACILITIES



- ASDACS HAS  $\geq 4$  SA CAPACITY AND X-LINKS TO DDS
- OPERATIONAL DDS DOES DIRECT DISTRIBUTION AND HAS INCREASED CAPACITY OVER DEMO DDSS
- DDS ALSO SUPPORTS SUBSTANTIAL NETWORKING LOAD AMONG MAJOR FACILITIES AND END USERS

KEY:

- ATRSS
- ASDACS
- DDS (DEMONSTRATION)
- DDS (OPERATIONAL)
- ▲ AGT
- △ AGT EVOLUTION

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Exhibit 1-6: Potential Route for ATRSS/FSG Evolution to ASDACS/FSG Conus Gateway Architecture

#### 1.4.4 Demonstration DDS Description

The primary rationale for the demonstration Data Distribution Satellite is to support the smooth transition to the climax CONUS Gateway architecture in the ATDRSS timeframe. With the proper payload on the ATDRSS/FSG to support the interface with the DDS, all the key operational capabilities of the climax CONUS Gateway architecture can be demonstrated and instituted in the ATDRSS timeframe. These capabilities include:

- Direct distribution of space data to Major Facilities and End User VSATs.
- Interactive operations of space payloads from VSATs.
- Wideband networking among all major facilities.
- Wideband access to Major Facilities from VSATs for data retrieval and supercomputer access.

Exhibit 1-7 summarizes the key target requirements of the demonstration DDS payload and illustrates the various payload components. The envelope capacity for space data distribution is roughly 1.2 Gbps which is large enough to support at least one ultra-high data rate channel from each ATDRS. In addition, a networking capacity of up to 2 Gbps between Major Facilities is provided. The subsystems of the proposed demonstration DDS are follows:

- The SGL Subsystem: this contains a high gain transmitter, a high gain receiver, and a CONUS coverage receiver/transmitter.
  - The high gain transmitter implementation is a Ka-band phased array feed antenna with 8 hopping 0.3° beams that can scan all of CONUS. The power of each beam is between 2 and 20 watts, adaptive to rain degradation. The data rate supported by each beam is 300 Mbps to Major Facilities and 150 Mbps (rate 1/2 coded) to End User VSATs. Higher data rates to major facilities are supported via assignment of multiple beams.
  - The high gain receiver is also at Ka-band and supports ten fixed 0.3° beams distributed over CONUS so as to provide coverage to all Major Facilities. Each beam supports 300 Mbps.
  - The CONUS receiver/transmitter provides a shaped duplex beam at Ku-band covering all of CONUS. The transmit end supports a 1 Mbps TDM downlink for space data, and the receive end supports one or more 100 Kbps uplink random access channels.
- The Processing and Routing Subsystem: this includes a CCSDS processing capability for space data, and additional processing capability for the switching and routing of networking data.
- The Crosslink Subsystem: this includes the modems and codec for the ATDRSS space-space channels, and the two optical terminals that support the links to the two ATDRS.

### DEMONSTRATION DDS COMMUNICATIONS PAYLOAD DRIVERS

- Constraints: must be compatible with the crosslink interface of the ATDRSS/FSG - assume optical crosslink interface
- Objectives: validate and support ATDRSS transition/evolution toward the CONUS Gateway architecture
- Applicable timeframe: 2005 or shortly thereafter
- Target requirements:
  - Direct distribution of return space data
    - ♦  $\approx$  1.2 GBPS total capacity to Major Facilities
    - ♦  $\approx$  1 MBPS total capacity to End Users
    - ♦ on-board CCSDS packet processing & switching
  - Direct link for forward space data
    - ♦  $\approx$  100 MBPS capacity from Major Facilities
    - ♦  $\approx$  100 KBPS capacity from End Users
    - ♦ CCSDS packet processing & switching
  - Two crosslinks (up to 80° Geo arc) with ATDRSS/FSG
    - ♦  $\approx$  600 MBPS receive data rate
    - ♦ 100 MBPS transmit data rate
    - ♦ On-board modems/codecs for space-space channels
  - Networking of ground elements (e.g., Supercomputer highway)
    - ♦  $\approx$  2 GBPS total capacity between Major Facilities (300 MBPS links)
    - ♦ 150 MBPS links from Major Facilities to selected End Users.

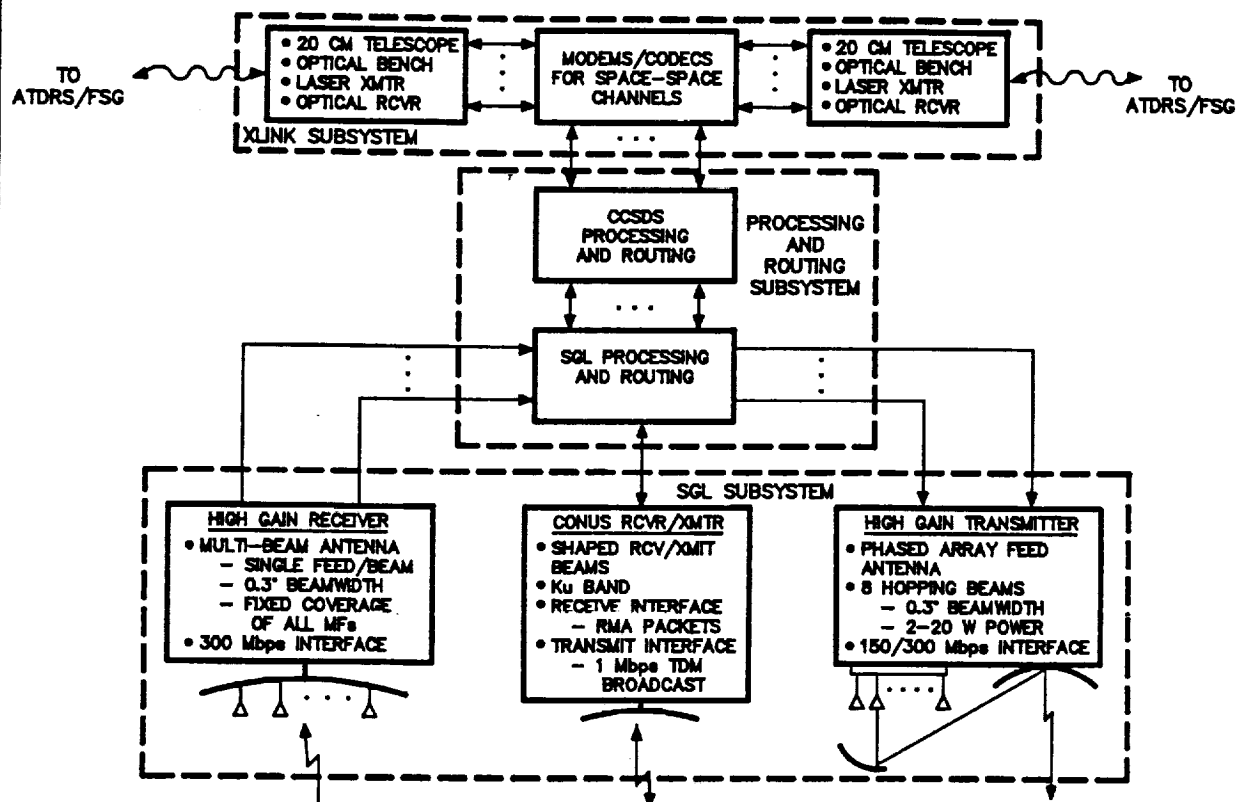


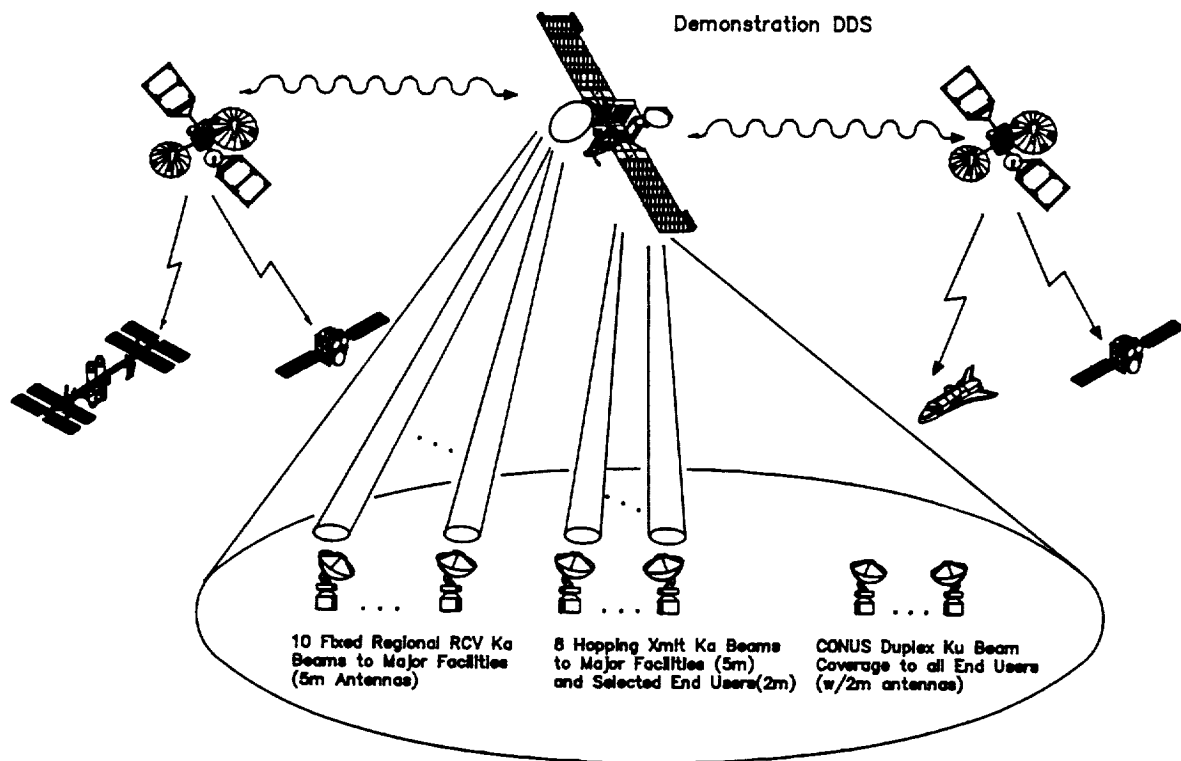
Exhibit 1-7: Demonstration DDS Communications Payload Drivers

The demonstration DDS, in conjunction with ATDRSS constitute an interesting hybrid architecture in which one pair of ATDRS stationed at 41° and 171° West are supported directly via White Sands and a second pair are supported via the DDS. Exhibit 1-8 illustrates the segment of the system supported by the DDS. The system architecture and operations of the other two ATDRS are unchanged from the ATDRSS baseline. The DDS-supported ATDRS are provided flexible high data rate connectivity to many Major Facilities, and a 1 Mbps broadcast capability to 1000s of End User VSATs. Exhibit 1-8 also illustrates an artists concept of the DDS which clearly shows the transmit and receive multi-beam antennas, the optical crosslink terminals, and the CONUS coverage antenna.



## SYSTEM ARCHITECTURE INCORPORATING A DEMONSTRATION DDS

TWO OF FOUR ATDRS ARE CONNECTED TO GTs Via The DDS



## DATA DISTRIBUTION SATELLITE

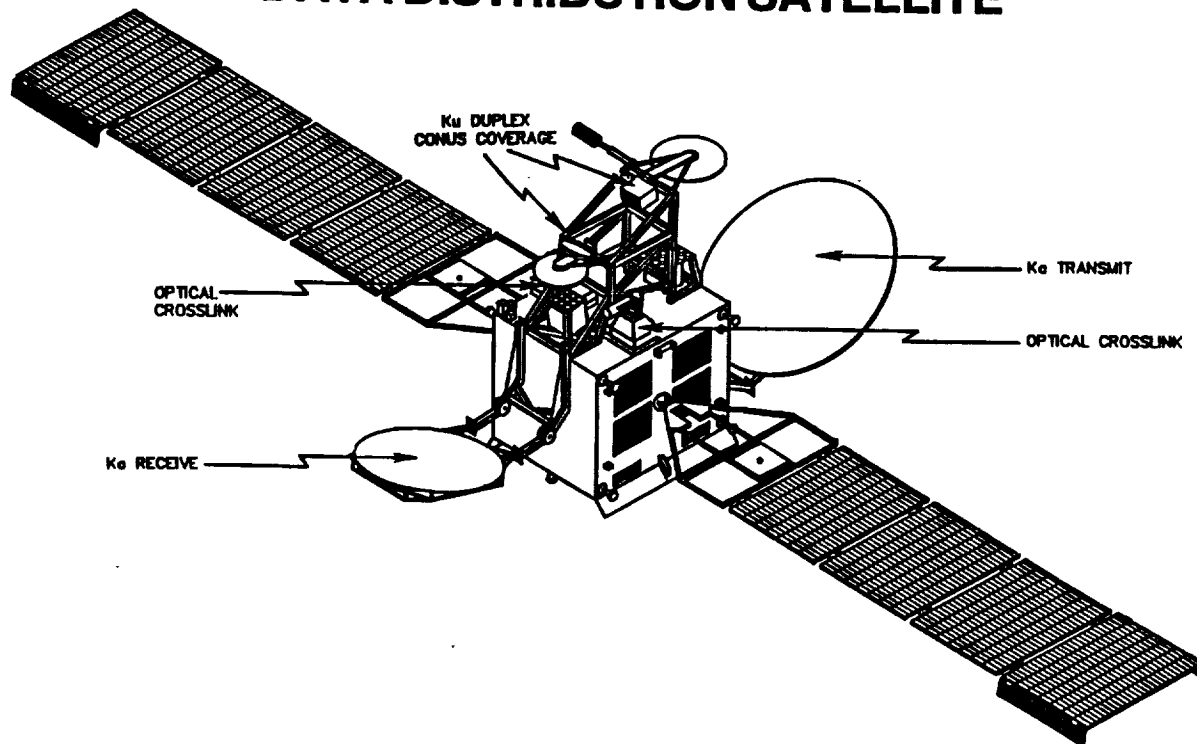


Exhibit 1-8: Demonstration DDS and System Architecture

5/21/01 TR91023/RB5417

#### **1.4.5 Mass/Power/Cost Estimates**

The table in Exhibit 1-9 summarizes the mass and power estimates for the communications payload of the demonstration DDS. The sources of the data base used to generate the estimates encompass numerous payload studies for ATDRSS and several other studies of advanced communications payloads. The bottom line payload figures of 980 lbs. and 1669 watts are well within the envelope of currently considered payloads for communications satellites. With respect to the satellite bus, the 5000 series bus of General Electric can probably support a total mass of somewhat more than 6000 lbs. at liftoff and a total power of 3 KW at end of life. The mass envelope is roughly consistent with the following DDS mass requirements for the spacecraft, stationkeeping fuel, and apogee kick motor (AKM):

- Spacecraft dry weight: 2584 lbs
- Stationkeeping fuel (10 years): 600 lbs
- AKM (partially loaded Thiokol Star 488-17): 3200 lbs

Thus the total weight estimate at liftoff is about 6500 lbs. This is clearly compatible with either an Atlas IIAS/Centaur launch or a Titan III launch. It is worth noting that it only slightly exceeds the launch capability for an Atlas IIA/Centaur.

Exhibit 1-8 also summarizes the cost estimates for the demonstration DDS. The payload and spacecraft bus costs were generated using the USCM6 cost model. The outputs are in 1986 dollars. The launch cost cited is based upon 1990 data and is in 1990 dollars. As expected, the cost of any new one-of-a-kind spacecraft is considerable. However, over half of the cost is attributed to non-recurring payload costs. If a significant technology development program is mounted throughout the 90's in support of DDS-like payload capabilities, the actual non-recurring cost is expected to be much less. Furthermore, any DDS program purchasing multiple copies will reap the significant unit cost reduction by spreading the non-recurring costs over the spacecraft copies. Learning curve phenomena will also promote cost reduction. The unit costs for 2 spacecraft and 10 spacecraft are tabulated in Exhibit 1-9 and are believed to represent reasonable upper and lower unit cost bounds. In summation, the cost of a demonstration DDS is expected to be in the range of 250 million to 500 million dollars.

SYSTEM ELEMENTS	WEIGHT (LBS)	POWER (WATTS)
HIGH GAIN RCV SGL	180	125
HIGH GAIN XMIT SGL	272	738
DUPLEX CONUS SGL	50	126
SWITCHING AND ROUTING	80	360
CROSSLINK TERMINALS	102 (X2)	90(X2)
PROCESSING OF SPACE-SPACE CHANNELS	112	140
TOTAL PAYLOAD	980 (W/- 10 % REDUNDANCY ALLOWANCE)	1669
SPACECRAFT (GB 500 SERIES BUS)	2584 LBS (DRY WEIGHT)	3 KW (EOL)

<ul style="list-style-type: none"> <li>COST FOR BUY OF 1 S/C:</li> </ul>			
USCM6 COST MODEL (86\$)			
ITEM	NON-RECURRING	RECURRING <sup>~</sup>	TOTAL
S/C	670 M\$ (= 80% P/L) (= 20% BUS)	240 M\$ (= 70% P/L) (= 30% BUS)	910 M\$
LAUNCH <sup>™</sup>	-	= 100 M\$	= 100 M\$
<ul style="list-style-type: none"> <li>LOWER BOUND UNIT COST: 254.8 M\$ <ul style="list-style-type: none"> <li>- 10 S/C BUY</li> <li>- 80% LEARNING CURVE</li> </ul> </li> <li>UPPER BOUND UNIT COST: 530.6 M\$ <ul style="list-style-type: none"> <li>- -2 S/C BUY</li> <li>- 80% LEARNING CURVE</li> </ul> </li> </ul>			

Exhibit 1-9: Summary Mass/Power/Cost Estimates for Demonstration DDS Payload and Spacecraft

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<sup>~</sup> INCLUDES AKM

<sup>™</sup> ATLAS IIAS/CENTAUR OR TITAN III

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**SECTION 2****DDSS REQUIREMENTS DEFINITION**

The requirements for the DDSS incorporate the areas of direct distribution of space data, interactive space operations, and networking. This section describes the approach toward developing requirements in these categories and discusses the resulting requirements envelopes.

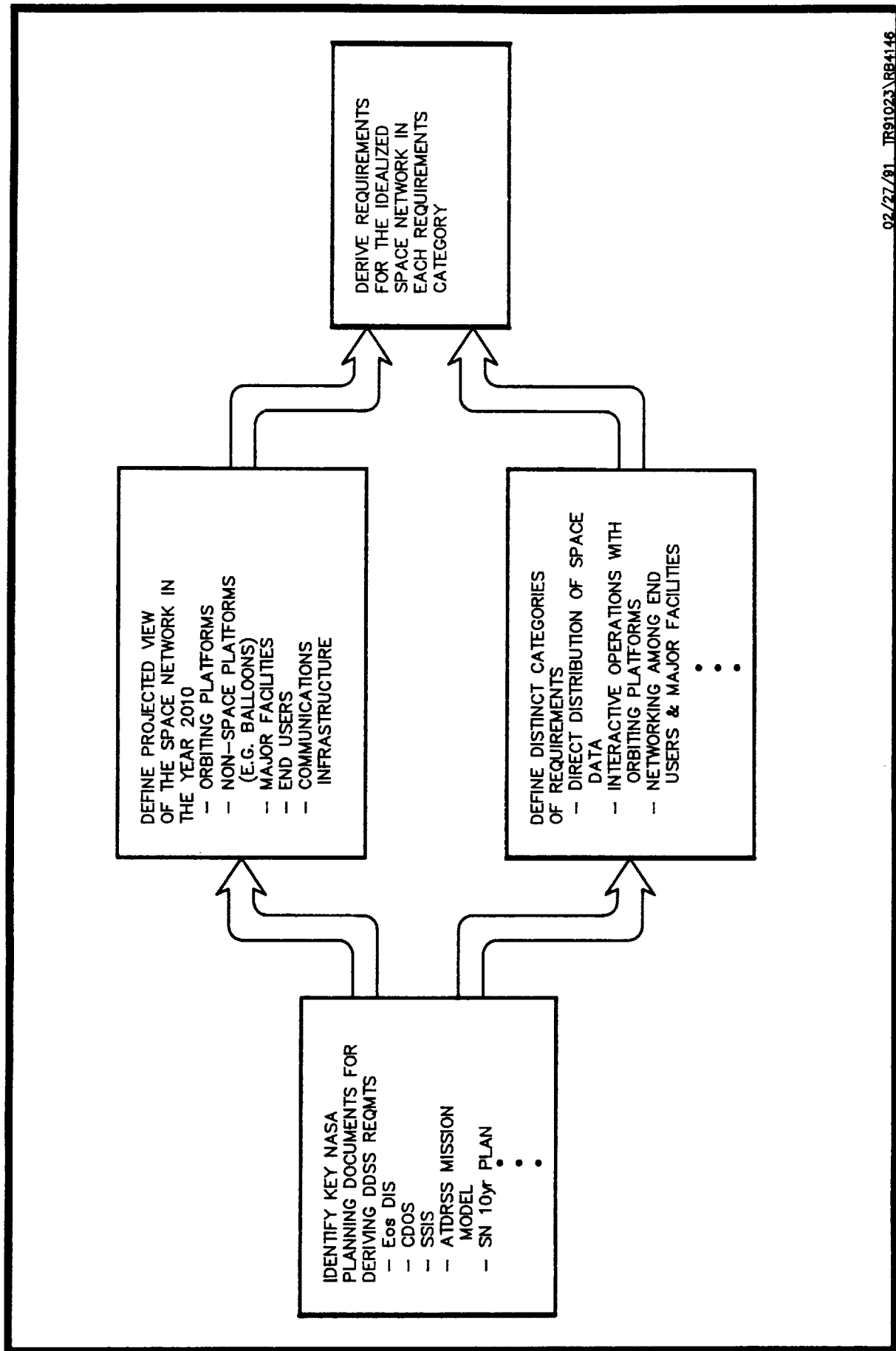
## **2.1 APPROACH TO REQUIREMENTS DEFINITION**

In developing long term requirements projections out to 2010, it is important to base requirements on broad trends rather than specific details. In this way, the requirements developed are robust in that they do not depend strongly on detailed user characteristics and mission scenarios. This approach is also necessitated by the fact that detailed user descriptions and mission scenarios applicable to 20 years down the road are typically not available.

Exhibit 2-1 illustrates the approach taken toward requirements definition. The basis for all requirements identified for the DDSS are NASA documents and studies including the following:

- The ATDRSS Mission Model [1]
- The Customer Data and Operations System (CDOS).
  - Project Management Plan [2]
  - Level I and II Requirements [3, 4]
  - Concept Definition [5]
  - Operations Concept [6]
- EoS DIS
  - Baseline Report [7]
  - Data Transfer and Data Communications Requirements Study [8]
- Information System Scenarios for Space Science and Applications [9]
- Space Station Information System (SSIS) [10]

These and other documents were used to characterize users of the DDSS and project their requirements.



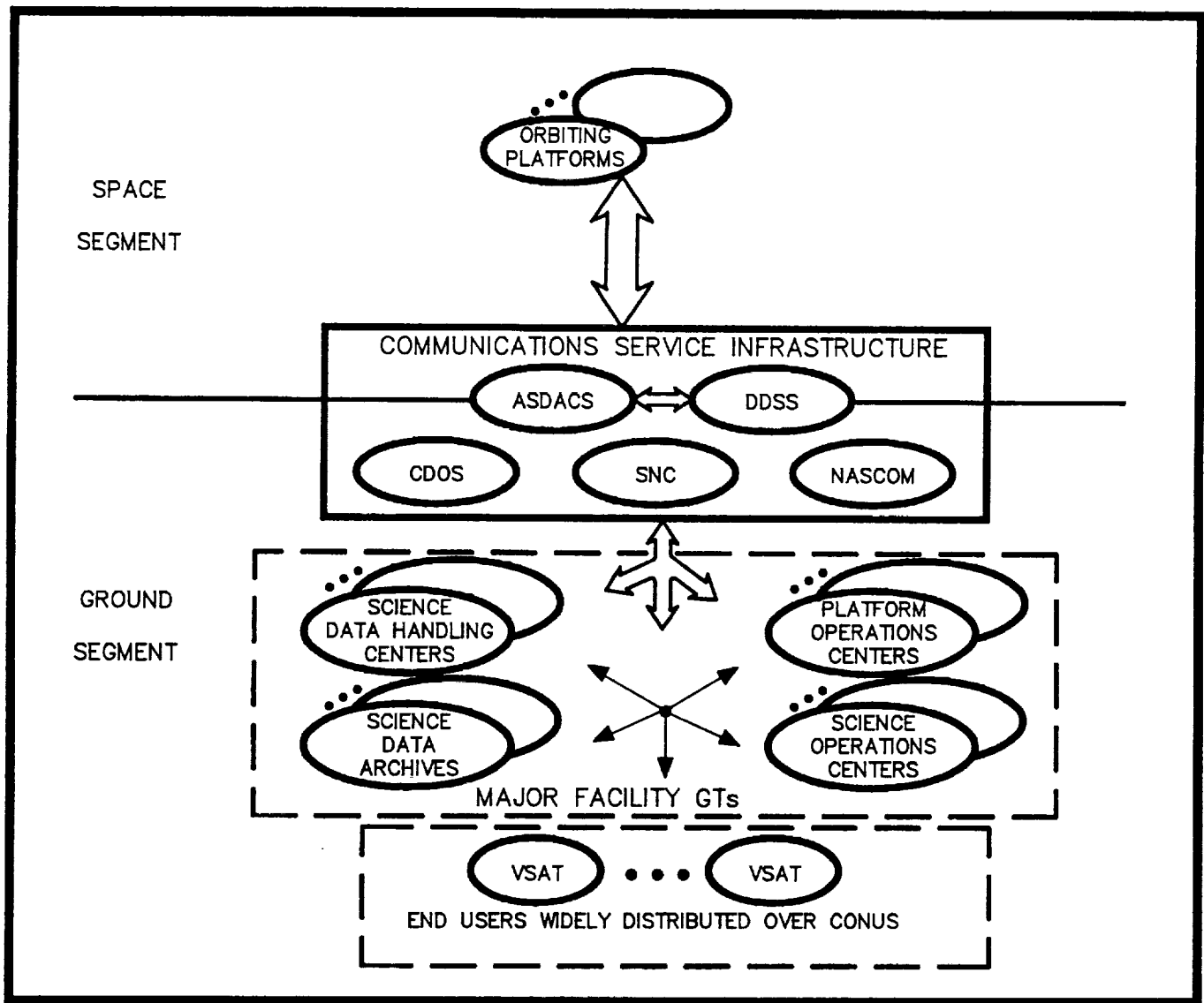
## **2.2 DESCRIPTION OF REQUIREMENTS**

Exhibit 2-2 illustrates the projected view of NASAs Space Network beyond the year 2010. The communications infrastructure of the network is composed of the ASDACS (the follow-on to ATDRSS) and the DDSS, the Space Network Control (SNC), and the data distribution elements of CDOS and NASCOM. The users of the Network fall into three categories. These are:

- **Orbiting Space and Other Airborne Platforms**
- **Major Facilities**
  - **Science Data Handling Centers (SDHCs):** Science Data Processing and Super Computing
  - **Science Data Archives (SDAs):** Provides data storage and access to archives
  - **Science Operations Centers (SOCs):** Controls science instruments and plans the science mission activities
  - **Platform Operations Centers (POCs):** Controls the orbiting space platforms and plans platform activities
- **End Users:** Individual investigators and other non-institutional DDSS users

While Space Platforms and Major Facilities are relatively few in number (i.e., dozens), the number of End Users is quite large, and they are widely distributed. Also, since one of the goals is to provide low cost and friendly access to space data, the End User communications capability is assumed to be consistent with that of Very Small Aperture Terminals (VSATs) for satellite communications.





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Exhibit 2-2: Simplified View of the Space Network and Users Beyond 2010

DDSS user requirements have been grouped into three categories. These are as follows:

- Direct distribution of platform data to data processing/archiving facilities and end users
  - Support rapid and efficient access to space data
  - Platform data storage dumps
  - Real-time science and engineering data
- Interactive operation of space platforms and instruments
  - Support demand access in real-time
  - Platform command uploads and acknowledgement
  - Telescience, telerobotics and teleoperations
  - Ground-crew interactions via voice and video
- Networking of the community of facilities and end users involved in space science and space operations
  - Peer networking among end users
  - Major Facility connections
  - End Users access to major facilities (e.g., archives and super computing facilities).

The requirements of each of these categories is discussed below. Each category is characterized by a figure showing the required connectivity, the number of required channels and their data rates, and a traffic description.

Exhibit 2-3 illustrates a representative user set and peak load requirement for direct distribution of space data. The point of origin the data (specific Orbiting Platforms) are listed, along with the ultimate data destinations at Major Facilities and End Users. This information in this table is based primarily upon the ATDRSS Mission Model for 2010 and the capabilities projected for ATDRSS [1]. The ATDRSS will provide up to eight single access (SA) channels each capable of supporting up to 650 Mbps, and up to 20 multiple access (MA) channels, each at up to 50 Kbps. The total data rate envelope for the projected missions in 2010 is 529 Mbps. However, because the ATDRSS SA service will be able to provide up to 650 Mbps, a sizable requirements growth is expected. We have chosen here a 2 Gbps maximum envelope for data distribution which is approximately equivalent to 3 simultaneous SA channels operating at 650 Mbps.

LINKS TO ORBITING PLATFORMS			ASSUMED LINKS TO DATA DESTINATIONS			
NAME	CONTACT HRS/DAY	PEAK RTN DATA RATE	NUMBER	RANGE OF DATA RATES	NUMBER	RANGE OF DATA RATES
1. SSF MB	24	70 Mbps	10	T1 - 70 Mbps	1000s	4 Kbps - T1
2. POPs	24	300 Mbps	3-5	T1 - 300 Mbps	1000s	4 Kbps - T1
3. STS	24	50 Mbps	5-10	T1 - 50 Mbps	1000s	4 Kbps - T1
4. MOTV	24	50 Mbps	1	50 Mbps	---	---
5. AXAF	3	0.5 Mbps	1	4Kbps - 0.5 Mbps	100s	4 Kbps - 0.5 Mbps
6. INTEGRAL	0.4	2.5 Mbps	2	0.1 - 2.5 Mbps	100s	4 Kbps - T1
7. STFO	7	1 Mbps	1	1 Mbps	100s	4 Kbps - 1 Mbps
8. ROTV	8	54 Mbps	1	54 Mbps	---	---
9.-28. GENERIC MA USERS	2-24	50 Kbps ea	5	4-50 Kbps	1000s	4 - 50 Kbps
TOTALS	---	529 Mbps	25-35 AT 10 GEOGRAPHICALLY DISTINCT LOCATIONS	---	1000s	---

ADAPTED FROM ATRSS 2010 MISSION MODEL: "ATRSS SPACE NETWORK MISSION FORECAST AND LOADING ANALYSIS", GSFC/MODSD BRIEFING, 5 SEPTEMBER 1990

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Exhibit 2-3: ASDACS/DDSS User Busy Day Peak Load Requirements for Direct Data Distribution

Exhibit 2-4 further illustrates the data distribution requirement for the DDSS. The figure shows that direct data distribution requires return connectivity from Orbiting Platforms to selected Major Facilities and End Users. While the Major Facilities are few in number and clustered in about 10 locations, the End Users (which include all astrophysical and earth scientists that use data generated in space) number in the 1000's and are widely distributed over CONUS. Much of the data traffic, particularly to Major Facilities will be sent in long continuous streams, but a significant portion of data traffic to End Users will be bursty in nature.

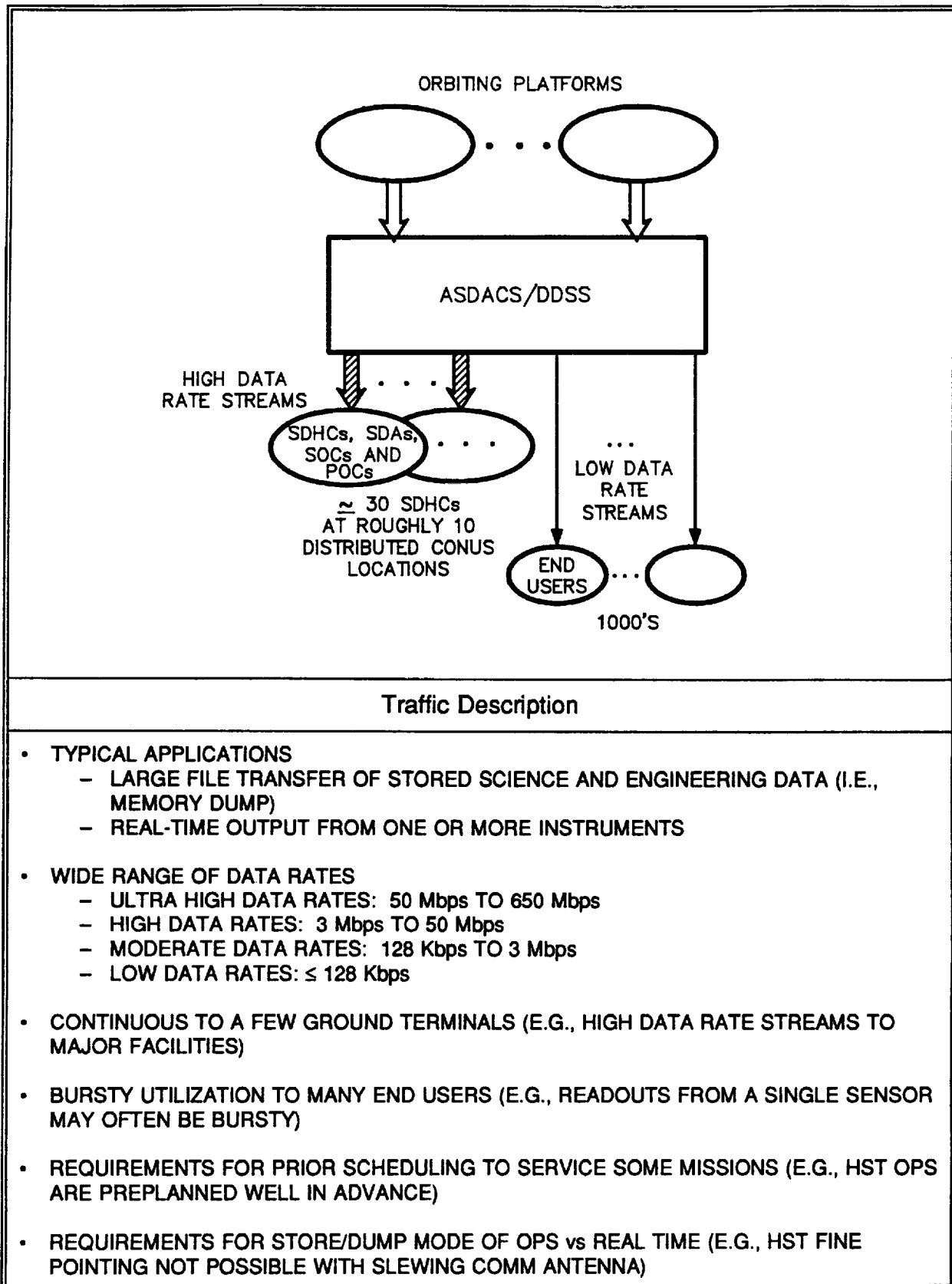


Exhibit 2-4: Direct Distribution of Space Data

Exhibit 2-5 illustrates the DDSS requirement for interactive space operations. Interactive operations require two-way links supporting forward and return services. This requirement could be served via a dedicated two-way link, but typically, the bursty nature of traffic in at least one direction raises the possibility of rapidly configured time-shared links to simulate a continuous two-way connection.

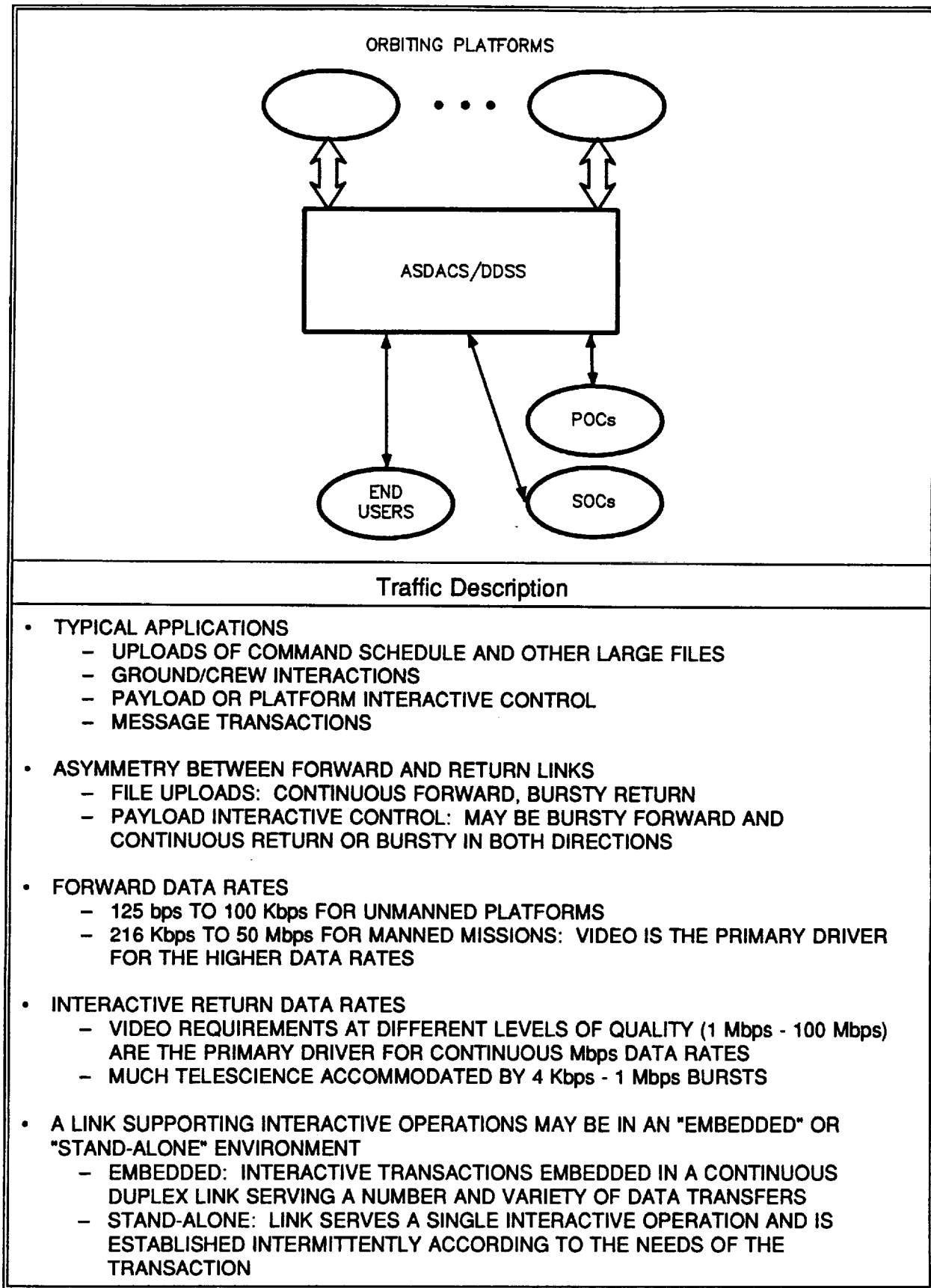


Exhibit 2-5: Interactive Operation of Space Platforms and Instruments

Exhibit 2-6 illustrates the DDSS requirement for networking among Major Facilities and End Users. It is important to note that such networking is the biggest driver for DDSS throughput. By far, the discipline where the most data will be generated and processed is earth science. The entries in the table of Exhibit 2-6 are consistent with the continuous generation of about a 100 Mbps of data in space, and about a factor of 10 multiplier for providing the network to support the subsequent processing, reprocessing and archive storage/retrieval envisioned. This factor of 10 multiplier is traceable to the EoS DIS Data Transfer and Data Communications Requirements Study [8].



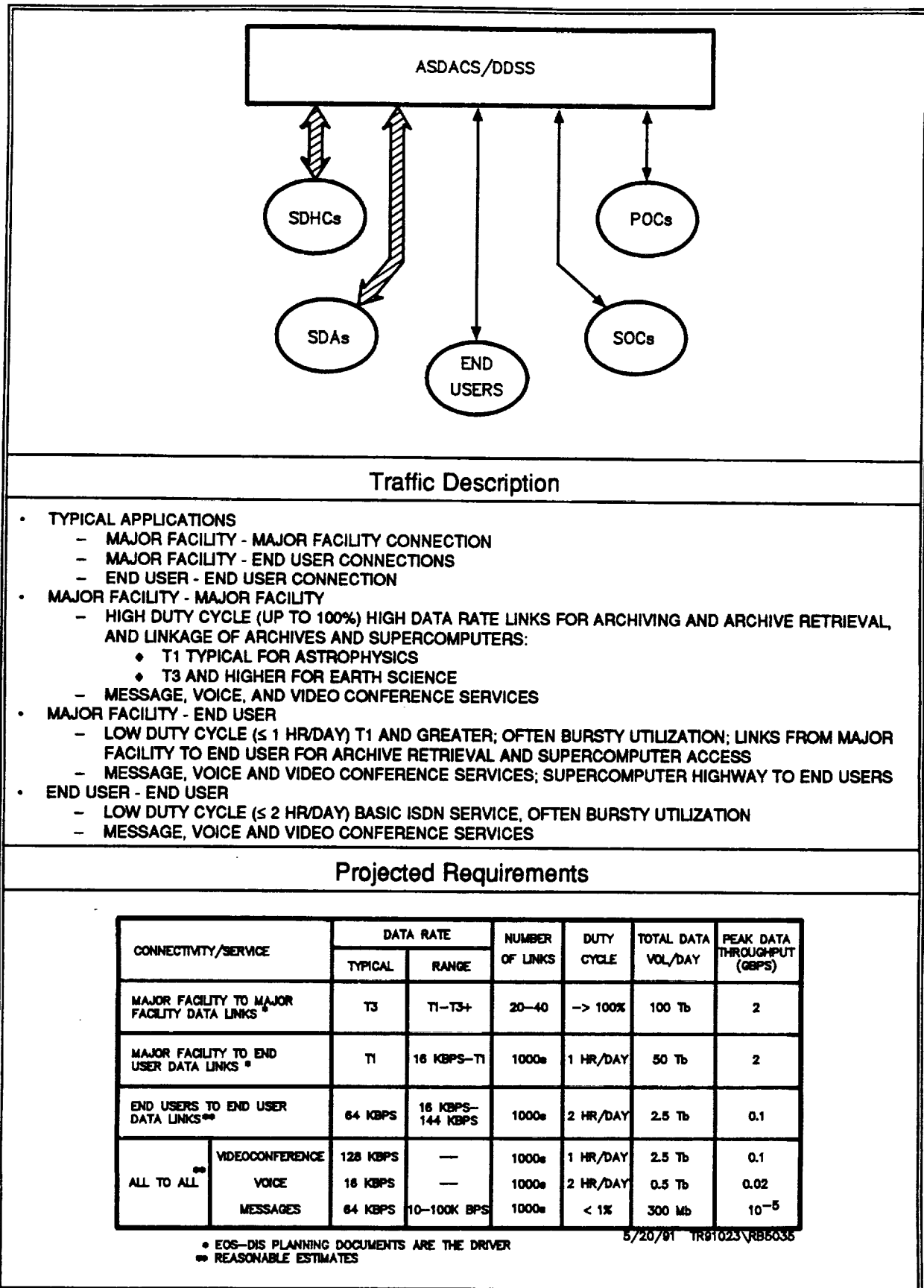


Exhibit 2-6: Networking of Major Facilities and End Users

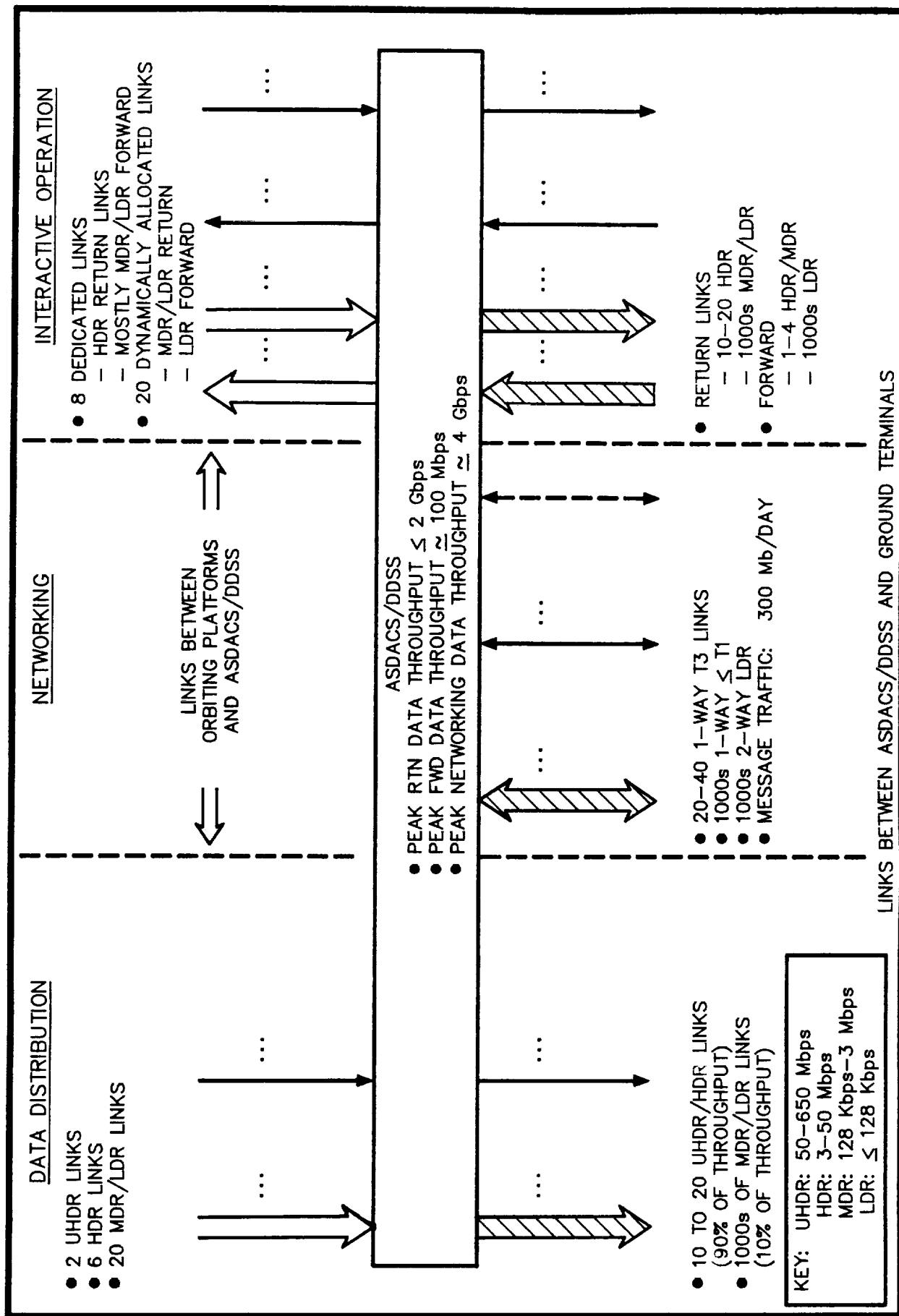
### 2.3 DDSS USER REQUIREMENTS SUMMARY

Exhibit 2-7 summarizes the total envelope of ASDACS/DDSS system requirements. The function of the ASDACS/DDSS combination system is to provide the following connectivities:

- Return links between Orbiting Platforms and ground users (Major Facilities and End User VSATs).
- Interactive links between Orbiting Platforms and ground users.
- Two-way links between the community of all Major Facilities and End Users.

These connectivities and the traffic required on the connections are the drivers for establishing the system requirements for ASDACS space-space links, DDSS throughput and DDSS space ground links. The key features in each of these areas are as follows.

- Space-space links connecting orbiting platforms with the ASDACS: The wide arrows represent HDR and UHDR links while the single line arrows represent the MDR and LDR links. Based upon the heritage of the planned ATDRSS architecture, there are 8 HDR/UHDR links and 20 MDR/LDR links.
- DDSS data throughput: The primary drivers for data throughput are networking of ground users, and return space data distribution. These account for 4 Gbps and 2 Gbps respectively, for a total peak processing envelope of up to 6 Gbps.
- Space-ground links connecting the DDSS with Major Facility and End User terminals. These links again are grouped into HDR/UHDR categories and MDR/LDR categories. Typically, the HDR/UHDR links will be with Major Facility terminals, and the MDR/LDR links will be with End User VSAT terminals.



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Exhibit 2-7: Summary of ASDACS/DDSS System Requirements

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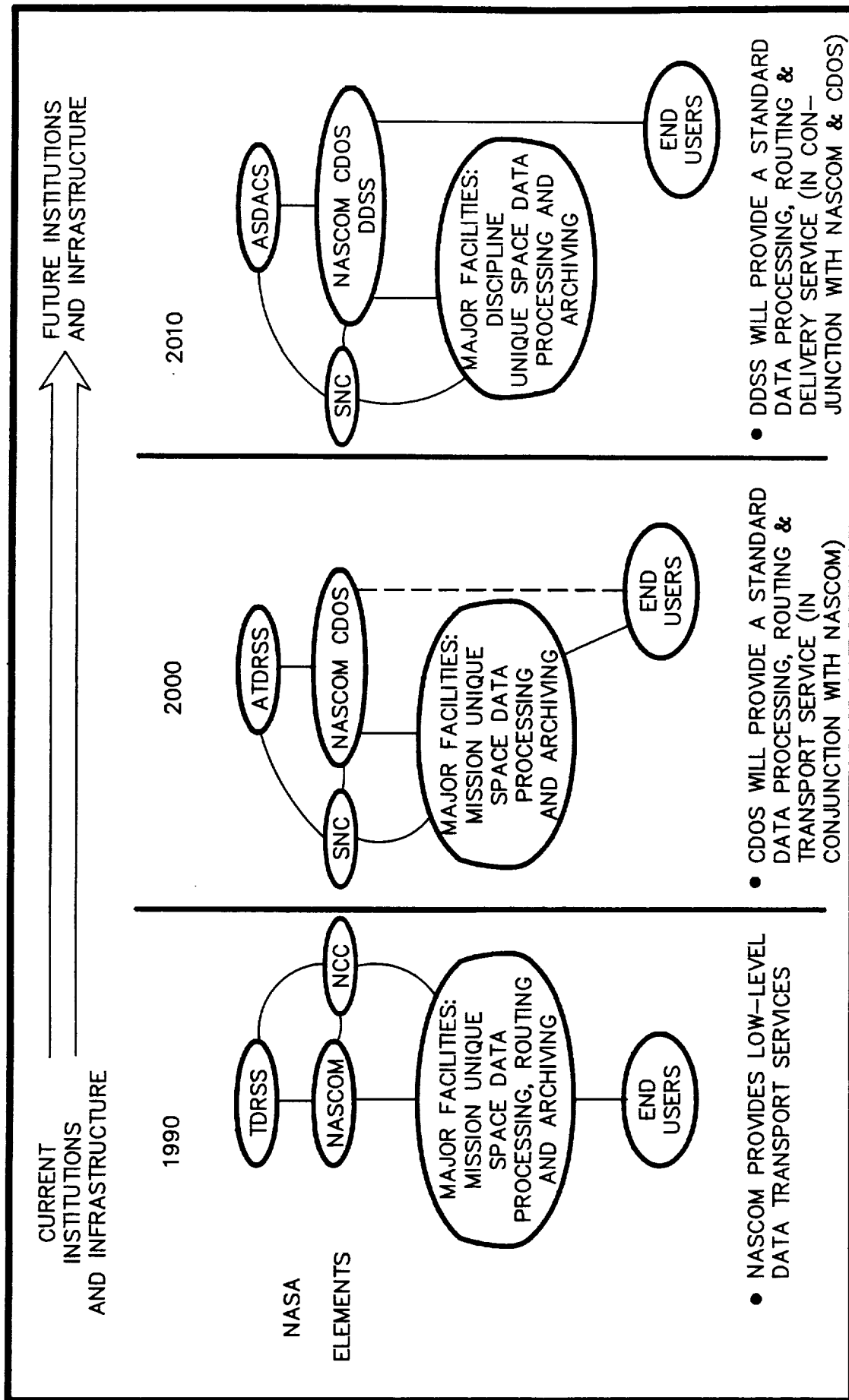
## SECTION 3

### DDSS OPERATIONS CONCEPT

The DDSS operations concept describes how the communications infrastructure in NASA's space network will support the demanded services. A system's operations concept is typically evolutionary in nature as institutions and their functions adjust to technology insertion and demands for new services over time. The major shaping factors of the DDSS operations concept are the combined heritage of ATDRSS and space network operations out to 2010, and evolving commercial satcom architectures for small (VSATs) and medium-sized earth terminals. This section describes some of the features of the projected evolution in operations and services that will influence the definition of the DDSS.

### 3.1 EVOLUTION OF NASA'S SPACE NETWORK

Exhibit 3-1 illustrates a likely evolution of NASA's space network. At the current time, NASCOM is the chief intermediary providing data distribution services. The service provided is only low-level insofar as it provides a trunking capacity between the TDRSS and major facilities. Furthermore, no service at all is provided directly to End Users. End User access to data is only via links with Major Facilities. With the implementation of CDOS by the year 2000, the combined NASCOM/CDOS infrastructure will provide higher level services such as the generation and distribution of standard data products to Major Facilities. Limited direct data distribution to End Users may also be provided. By the year 2010, however, with the introduction of the DDSS, the combined NASCOM/CDOS/DDSS infrastructure will provide high-level services to both Major Facilities and End Users.



2/28/91 TR91023\RB5041

Exhibit 3-1: Evolution of NASA's Space Network to the Year 2010

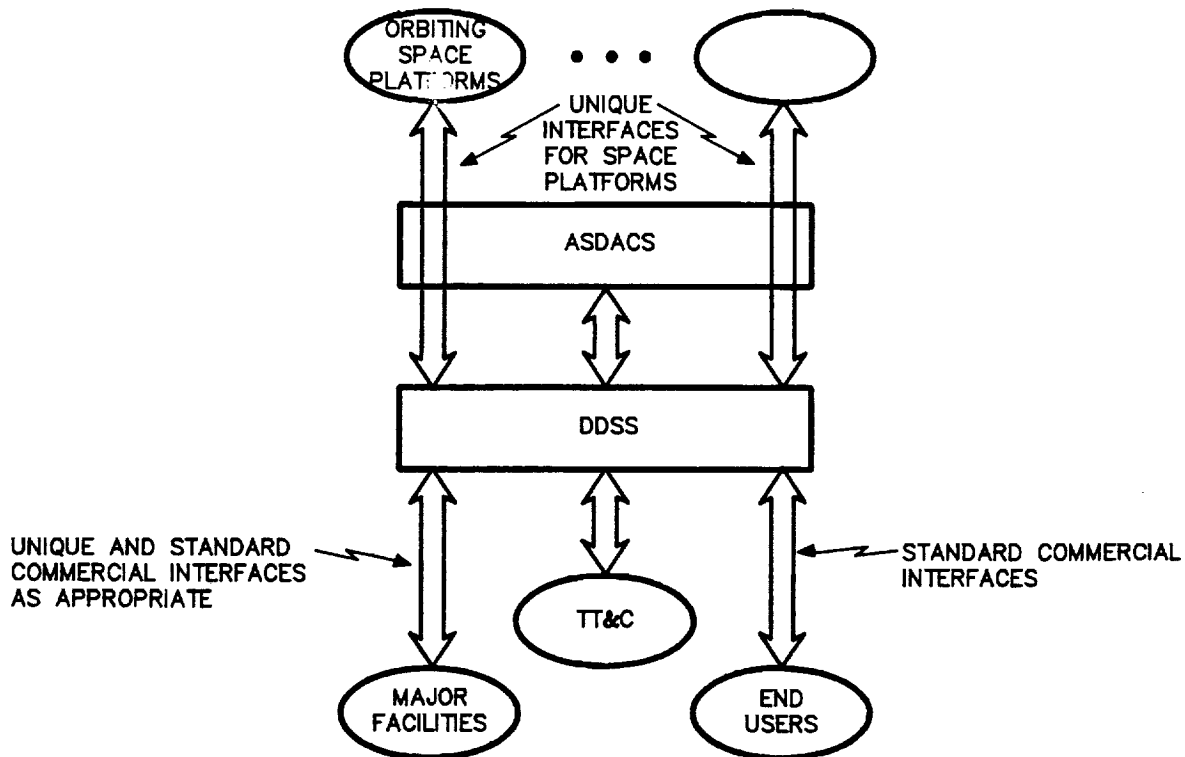
### 3.2 FUNCTIONAL ALLOCATIONS AND INTERFACES

Exhibit 3-2 illustrates the philosophy behind the functional allocation and interfaces of the combined DDSS/ASDACS.

The ASDACS serves the interface with Orbiting Platforms. Given the constrained resource environment for Orbiting Platforms, the ASDACS communication payload is assumed to provide a unique and flexible interface (such as standards developed by the Consultative Committee on Space Data Systems (CCSDS)) [11] to this user community in order to avoid placing needless constraints on these platforms and nurture maximum flexibility. In addition, this interface would embody a strong heritage of the previous ATDRSS system.

The DDSS serves the interface to earth terminals of Major Facilities and End Users. For maximum cost-effectiveness, these interfaces are assumed to be an evolution of standard commercial interfaces. Thus, a key function of the DDSS is to mediate between the unique interfaces with Orbiting Platforms supported by ASDACS, and the standard commercial interfaces with earth terminals supported by the DDSS. Thus, an End User with a standard commercial VSAT terminal of the future would have direct access to space data and payloads via such a terminal.





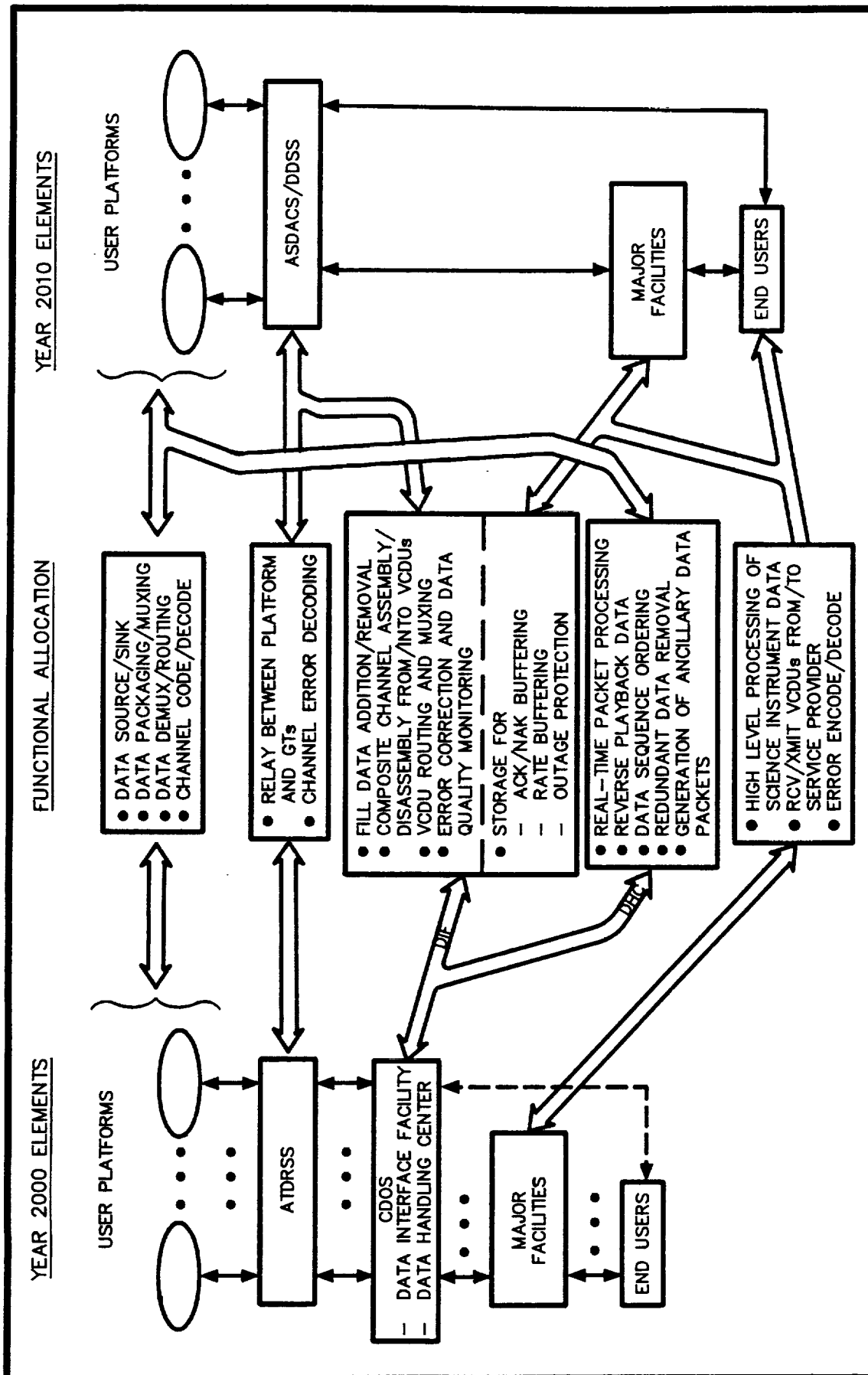
- ORBITING PLATFORMS
  - UTILIZE CCSDS—LIKE STANDARDS AND PROTOCOLS
  - UTILIZE UNIQUE MODULATION/CODING SCHEMES OPTIMIZED FOR THE SPACE COMMUNICATIONS ENVIRONMENT
- ASDACS
  - PROVIDES THE DIRECT LINK WITH ORBITING PLATFORMS
  - BENT PIPE RELAY BETWEEN PLATFORMS AND DDSS; ANY ON-BOARD PROCESSING IS ASSIGNED TO THE DDSS AS AN ASDACS PAYLOAD
- DDSS
  - RELAY BETWEEN ASDACS AND GROUND DESTINATIONS, AND BETWEEN GROUND USERS
  - PERFORMS MUX/DEMUX, SWITCHING AND ROUTING FUNCTIONS INCLUDING BASEBAND PROCESSING WHERE REQUIRED
  - PERFORMS THE CONVERSION BETWEEN CCSDS AND COMMERCIAL STANDARDS AS REQUIRED
- MAJOR FACILITIES: UTILIZE LARGE EARTH TERMINALS AND OTHER EQUIPMENT CONFORMING TO CCSDS AND/OR COMMERCIAL STANDARDS FOR DATA TRANSFER
- END USER UTILIZE SMALL EARTH TERMINALS AND OTHER EQUIPMENT CONFORMING TO COMMERCIAL STANDARDS FOR DATA TRANSFER

2/27/91 TR91023/RB5040

Exhibit 3-2: DDSS/ASDACS System Functional Allocation Interfaces

Exhibit 3-3 illustrates the logical evolution of functions within NASA's Space Network between the years 2000 and 2010. Five groups of functions are shown in the middle column of the exhibit and assignments of these functions between the two target years are indicated.

The first group of functions performed by Orbiting Platforms are expected to undergo little migration. Similarly for the second group of functions performed by ATDRSS in 2000 and by ASDACS/DDSS in 2010. In contrast, significant migration is expected in third and fourth group of functions allocated to the CDOS in 2000. The two cornerstones of CDOS will be the Data Interface Facility (DIF) and the Data Handling Center (DHC). The DHC functions are made necessary primarily by the absence of a random access storage medium for Orbiting Platforms in the year 2000. By the year 2010, new technology (such as optical read/write disks) will enable Orbiting Platforms to do data management and sorting prior to transmission. Thus, these functions will migrate to Orbiting Platforms and no longer need to be supplied by the Network. The DIF functions incorporate two classes of functions: those such as routing and muxing which can be done in real-time, and those such as storage for outage protection. Real-time functions will migrate to the ASDACS/DDSS which will do the necessary on-board processing to route data to various ground destinations. However, functions requiring significant or long term storage will remain on the ground. But, since the ASDACS/DDSS routes data directly to Major Facilities, these functions will be provided at the Major Facilities and will not require system support. Finally, the fifth group of functions such as the processing of instrument data, as well as error encoding/decoding tailored to the source data, will stay with Major Facilities from the year 2000 to 2010. However, by 2010 these functions will also be done by End Users that receive direct data distribution from the ASDACS/DDSS.



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Exhibit 3-3: Logical Evolution of the Functional Allocations Within Space Network Elements

### 3.3 ATDRSS HERITAGE

Exhibit 3-4 summarizes key aspects of ATDRSS heritage showing the baseline space network and spacecraft configuration of the ATDRSS era. Note that all space-to-ground connections are via the ATDRSS ground terminals (AGTs), and from there, connections to the Major Facilities (POCCs and Science Data Centers) and supported via CDOS in concert with NASCOM.

The spacecraft functional configuration is of significance because it embodies the service types that ATDRSS will support on its space-space links to orbiting platforms [12, 13]. The three categories of services are as follows:

- **Single Access (SA) Service:** Provided via dedicated steerable antennas at S-band, Ku- and Ka-band frequencies (tri-frequency feeds). SA service is applicable to high data rate services, or missions requiring high EIRP and/or G/T.
- **Multi-Access (MA) Service:** Provided via a phased array at S-band. MA service is applicable to low and moderate data rate services.
- **Beacon:** LEO coverage with a 125 bps channel at S-band. Beacon service is applicable to system status messages and short user-directed data packets.

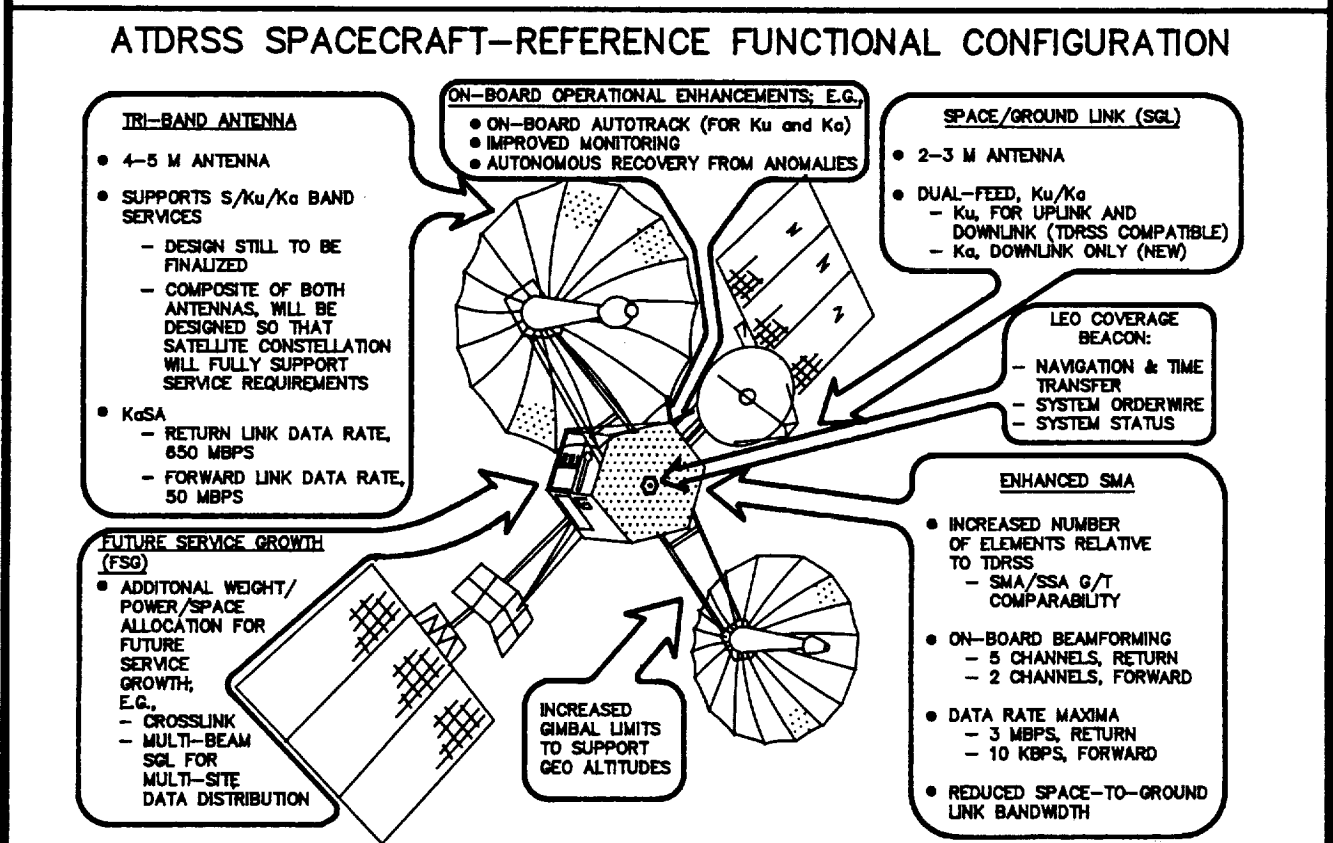
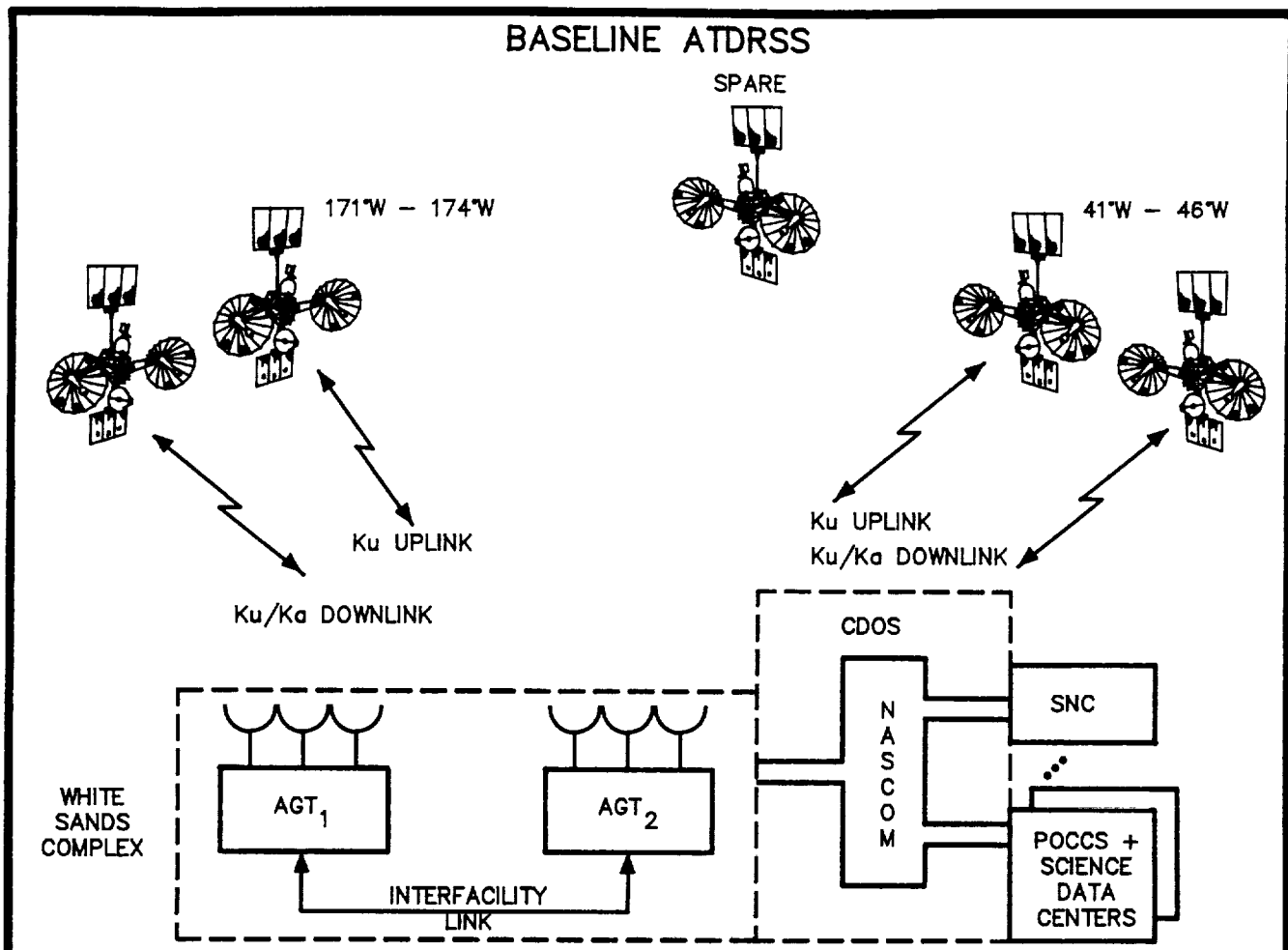


Exhibit 3-4: ATRSS Heritage

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### 3.4 EVOLUTION OF SERVICE CONCEPTS

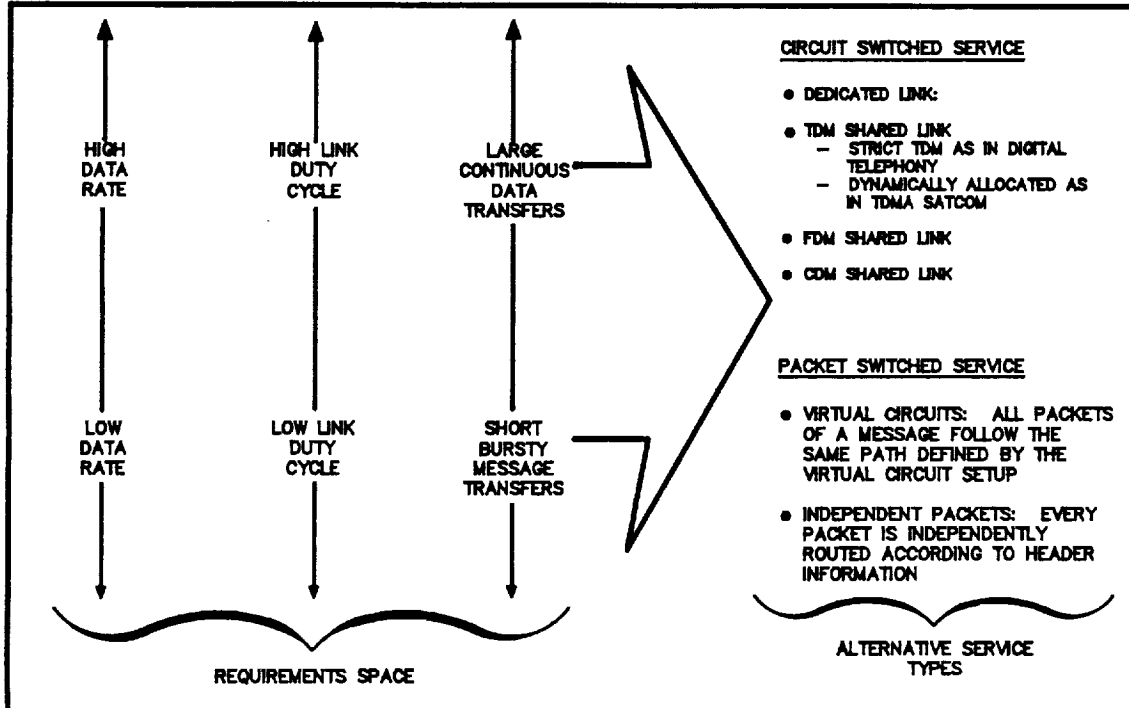
Exhibit 3-5 illustrates the rationale for space-space service evolution from 1996 to 2010, and a probable path for such evolution. The key rationale for evolution in the services offered by the ATDRSS is to provide a better match between services and applications. For example, TDRSS in 1996 offers essentially only a circuit-like service which dedicates a portion of the communications payload for the service duration. This is an efficient allocation for applications such as data storage dumps which are continuous and of long duration. But for applications such as interactions with space instruments, the traffic will be bursty and not efficiently serviced via a dedicated resource. Thus it is natural for the circuit-like service of the TDRSS era to evolve to more dynamic allocations now widely used in modern telecommunications.

Two popular forms of dynamic allocation are TDMA and packet-switched service. The seeds of both service types are already present in current TDRSS and ATDRSS concepts. For example, the TDRSS and ATDRSS MA service is provided via an S-band phased array which could be capable of rapid beam-steering needed for time division sharing. This is especially valuable for the forward link since in both TDRSS and ATDRSS, the forward MA links are fewer in number than the return links. Thus, a dynamically allocated forward link could be effectively time-shared among a number of return link users in order to support "two-way" services to those users with the time-shared forward link. For packet switching service, the LEO coverage beacon concept for the ATDRSS has the capability to support a low data rate ( $< 125$  bps) random access channel for short data packets directed to orbiting users. In the DDSS world, such a packet service could be provided via a similar beacon or possibly even via packet-switched control of the phased array antenna beam.

## EVOLUTION IN SPACE-SPACE COMMUNICATIONS SERVICE CONCEPTS

SERVICE			TDRSS (1996)	ATDRSS (2003)	ASDACS/DDSS (2010)	
SA	S-BAND	FORWARD	300 kbps	300 kbps	DEDICATED SINGLE ACCESS (DSA)	<ul style="list-style-type: none"><li>• FOR MODERATE TO ULTRA-HIGH DATA RATE CIRCUITS</li><li>• PROVIDED VIA ONE DEDICATED ANTENNA PER SERVICE</li><li>• CONTINUED EVOLUTION TO Ka-BAND</li></ul>
		RETURN	6 Mbps	6 Mbps		
	Ku-BAND	FORWARD	25 Mbps	25 Mbps		
		RETURN	300 Mbps	300 Mbps		
	Ka-BAND	FORWARD	N/A	50 Mbps		
		RETURN	N/A	650 Mbps		
	LINKS PER SPACECRAFT		2 SSA 2 KuSA	2 SSA 2 KuSA 2 KaSA		2-4
LINKS PER SYSTEM		8 SSA 8 KuSA	8 SSA 8 KuSA 8 KaSA	8 AT Ka-BAND		
SMA		FORWARD	4, EA @ 10 kbps	8, EA@ 10 Kbps	DYNAMIC MULTIPLE ACCESS (DMA)	<ul style="list-style-type: none"><li>• FOR LOW AND MODERATE DATA RATE CIRCUITS</li><li>• PROVIDED VIA DYNAMIC MA PHASED ARRAY</li><li>• 10 "DUPLEX" LINKS</li></ul>
		RETURN	20, EA @ 50 kbps	10, EA @ 3 Mbps		
BEACON		FORWARD	125 bps DEMONSTRATION CAPABILITY	125 bps	MESSAGE SERVICE	PACKET SWITCHED SERVICE FOR INTERMITTENT COMMUNICATIONS AND SYSTEM ORDERWIRE
		RETURN	VARIOUS DEMONSTRATION CAPABILITY	VARIOUS		

## MATCHING COMMUNICATIONS REQUIREMENTS AND SERVICE CONCEPTS



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Exhibit 3-5: Service Evolution Rationale and Direction

Exhibit 3-6 provides further insight into the definition of the three kinds of service envisioned for space platforms within ASDACS/DDSS. The three service types are as follows:

- **Dedicated Single Access (DSA) service:** This is essentially a circuit service typically reserved by schedule. The lead time for service reservation may be as long as a few weeks or as short as a few minutes.
- **Dynamic Multiple Access (DMA) service:** This is a circuit-like service which can be requested and configured with a short lead time of as little as a few seconds. Service reservation will typically be handled via a Demand Assigned Multiple Access (DAMA) protocol.
- **Message Transaction (MT) service:** This is a packet service which is accessed spontaneously via a Random Multiple Access (RMA) protocol. No lead time for service request/configuration is needed because the data packet contains the required routing information in its overhead.



### KEY FEATURES

SERVICE NAME	SERVICE TYPE		PRIMARY ACCESS PROTOCOL			TYPICAL LEAD TIME FOR ACCESS		
	CIRCUIT	PACKET	SCHEDULE	DAMA	RMA	MINUTES TO WEEKS	SECONDS	NONE
DEDICATED SINGLE ACCESS (DSA)	✓		✓			✓		
DYNAMIC MULTIPLE ACCESS (DMA)	✓			✓			✓	
MESSAGE TRANSACTION (MT)		✓			✓			✓

### DESCRIPTION AND EXAMPLE APPLICATION

SERVICE TYPE	DESCRIPTION	ACCESS PROCEDURE	EXAMPLE USAGE
DEDICATED SINGLE ACCESS (DSA)	<ul style="list-style-type: none"> <li>• CONTINUOUS <u>CIRCUIT</u> AT FIXED DATA RATE</li> <li>• SERVICE DURATION TYPICALLY &gt; 5 MIN</li> <li>• SINGLE ANTENNA BEAM AND/OR XPONDER IS DEDICATED TO ONE USER</li> </ul>	<ul style="list-style-type: none"> <li>• SERVICE IS ALLOCATED PRIMARILY VIA PRIOR SCHEDULING</li> <li>• SCHEDULE LEAD TIME WILL TYPICALLY BE ON THE ORDER OF WEEKS</li> <li>• SERVICE MAY ALSO BE DEMAND ASSIGNED</li> <li>• SYSTEM LOAD FACTOR IS HIGH: <math>\approx 80\% - 90\%</math></li> </ul>	<ul style="list-style-type: none"> <li>• SPACE DATA DISTRIBUTION: SPACE STATION TO ASDACS LINKS <ul style="list-style-type: none"> <li>- 300 Mbps RTN</li> <li>- 25 Mbps FWD</li> </ul> </li> <li>• NETWORKING: T3 LINKS BETWEEN MAJOR GROUND FACILITIES</li> </ul>
DYNAMIC MULTIPLE ACCESS (DMA)	<ul style="list-style-type: none"> <li>• CONTINUOUS OR PSEUDO-CONTINUOUS <u>CIRCUIT</u> AT FIXED DATA RATE</li> <li>• SERVICE DURATION MAY VARY FROM SECONDS TO HOURS</li> <li>• SINGLE ANTENNA AND/OR XPONDER RESOURCE SERVES MULTIPLE USERS VIA TIME, SPACE, FREQUENCY OR CODE DIVISION</li> <li>• CAN BE TRUE CIRCUIT OR FAST PACKET SWITCHING IMPLEMENTATION</li> </ul>	<ul style="list-style-type: none"> <li>• SERVICE IS ALLOCATED PRIMARILY IN REAL-TIME VIA DAMA PROTOCOL IN RESPONSE TO REQUEST ON SYSTEM ORDERWIRE CHANNEL</li> <li>• SERVICE MAY ALSO BE ALLOCATED VIA PRIOR SCHEDULING IF REQUIRED BY MISSION</li> <li>• SYSTEM LOAD FACTOR IS LOW (<math>\sim 50\%</math>) - EXCESS CAPACITY REDUCES CONFLICTS/BLOCKING TO AN ACCEPTABLE LEVEL</li> </ul>	<ul style="list-style-type: none"> <li>• INTERACTIVE OPERATIONS: MEDIUM SCALE FREE FLYER (FF) TO ASDACS LINKS: <ul style="list-style-type: none"> <li>- 1 Kbps FWD</li> <li>- 1 Mbps RTN</li> </ul> </li> <li>• DATA DISTRIBUTION: DDSS TO GROUND LINKS AT 50 Kbps (SS/FDMA) UP TO 100's OF Mbps (SS/TDMA)</li> <li>• NETWORKING: T3, T1 AND VOICE LINKS BETWEEN GROUND USERS</li> </ul>
MESSAGE TRANSACTION (MT)	<ul style="list-style-type: none"> <li>• <u>DATAGRAM PACKET</u> SERVICE FOR INTERMITTENT COMMUNICATIONS</li> <li>• SINGLE ANTENNA AND/OR XPONDER RESOURCE SERVICE MULTIPLE USERS VIA RMA PROTOCOLS</li> </ul>	<ul style="list-style-type: none"> <li>• WIDE VARIETY OF RANDOM MULTIPLE ACCESS (RMA) PROTOCOLS MAY BE USED FROM SIMPLE (ALOHA) TO COMPLEX</li> </ul>	<ul style="list-style-type: none"> <li>• INTERACTIVE OPERATIONS: SMALL SCALE FF TO ASDACS LINKS: <ul style="list-style-type: none"> <li>- 1 Kbps FWD</li> <li>- 50 Kbps RTN</li> </ul> </li> <li>• NETWORKING: MESSAGES BETWEEN GROUND USERS</li> </ul>

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Exhibit 3-6: Alternative Service Concepts

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## SECTION 4

### ALTERNATIVE SYSTEM ARCHITECTURES

In this section, alternative high-level DDSS architectures are defined and evaluated. The key subsystems for the architectures are developed and the major subsystem requirements are derived from the overall DDSS requirements.

## **4.1 DEFINITION OF ALTERNATIVES**

Exhibit 4-1 illustrates the process the developing the various system architectures for the DDSS concept. Starting from the general DDSS concept on the left, the first branch as we move right defines the two major classes of alternative architectures. The topmost branch pertains to the class of architectures that have a stand-alone Data Distribution Satellite (DDS) separate from the ASDACS. These architectures are referred to as the CONUS Gateway architectures because the DDS is placed above CONUS in geosynchronous orbit and serves as a communications gateway for all of CONUS. This gateway acts as a relay between different ground terminals, and between ground terminals and the ASDACS satellites which provide the connectivity to the Orbiting Platforms. The lower branch of architectures are referred to as Global Network architectures because these provide a global network that links together all the major facilities and end users worldwide. In this class of architectures the ASDACS and DDSS functions are integrated into a single spacecraft, and a number of such spacecraft (2-4) are placed around the geosynchronous arc, connected via crosslinks, thereby supporting the global network.

For both classes of architectures, additional branching occurs as we move to the right. These branches are distinguished by variations in the number of spacecraft, orbital spacing and other features that define the constellation. Finally, for each of these new branches, additional alternatives are distinguished by alternative implementations of the ASDACS and DDS communications payloads.

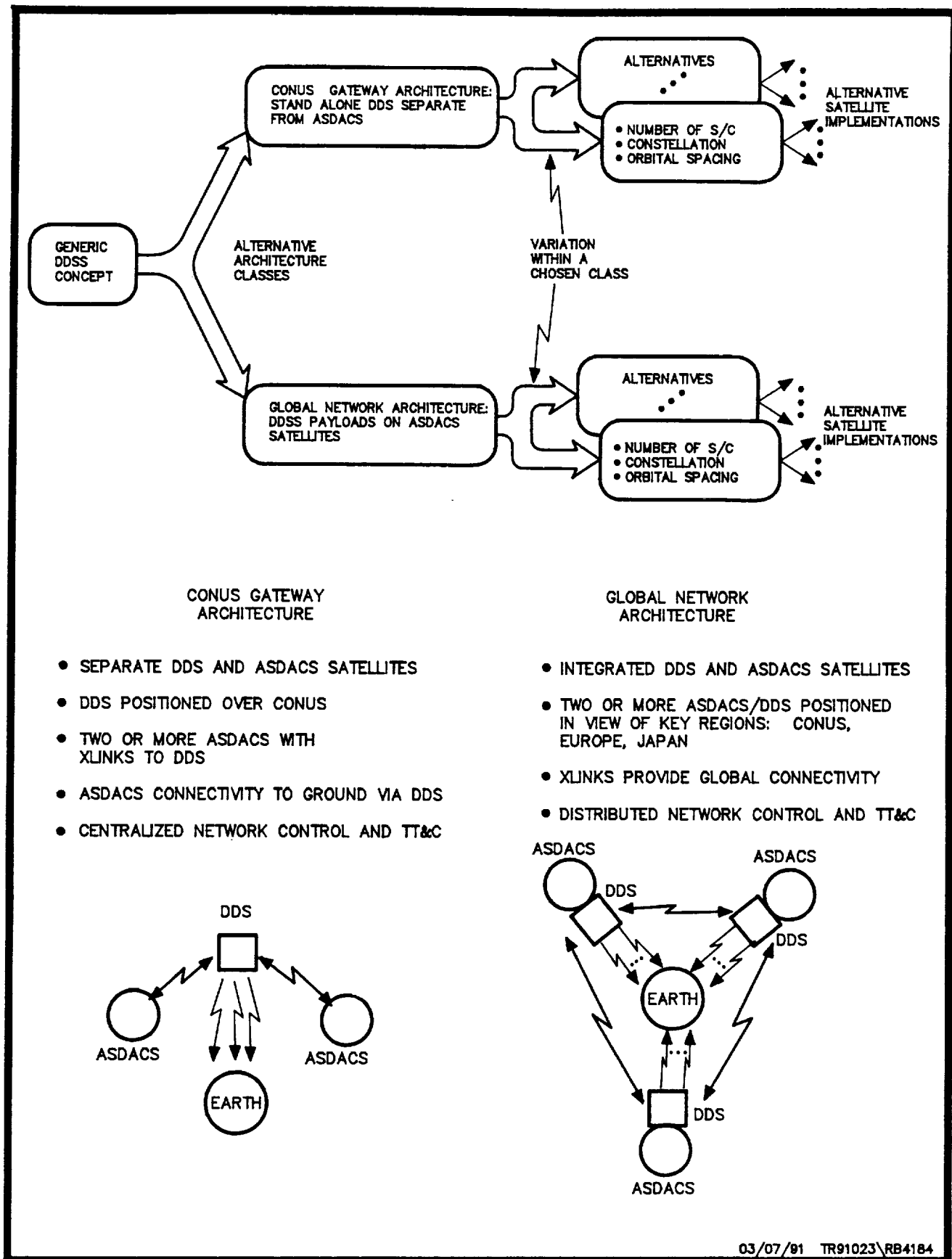


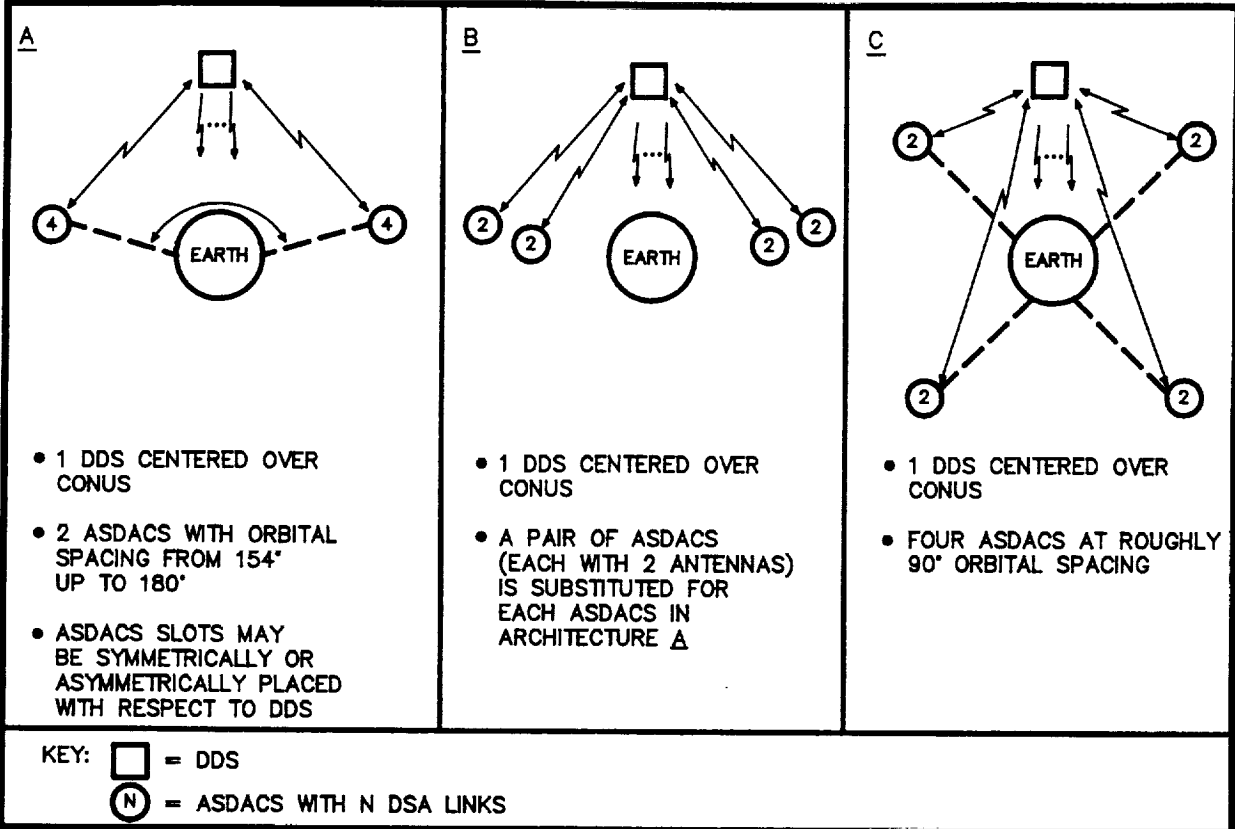
Exhibit 4-1: Defining Alternative Architecture

Exhibit 4-2 illustrates the variety of alternative constellations for the two classes of architectures.

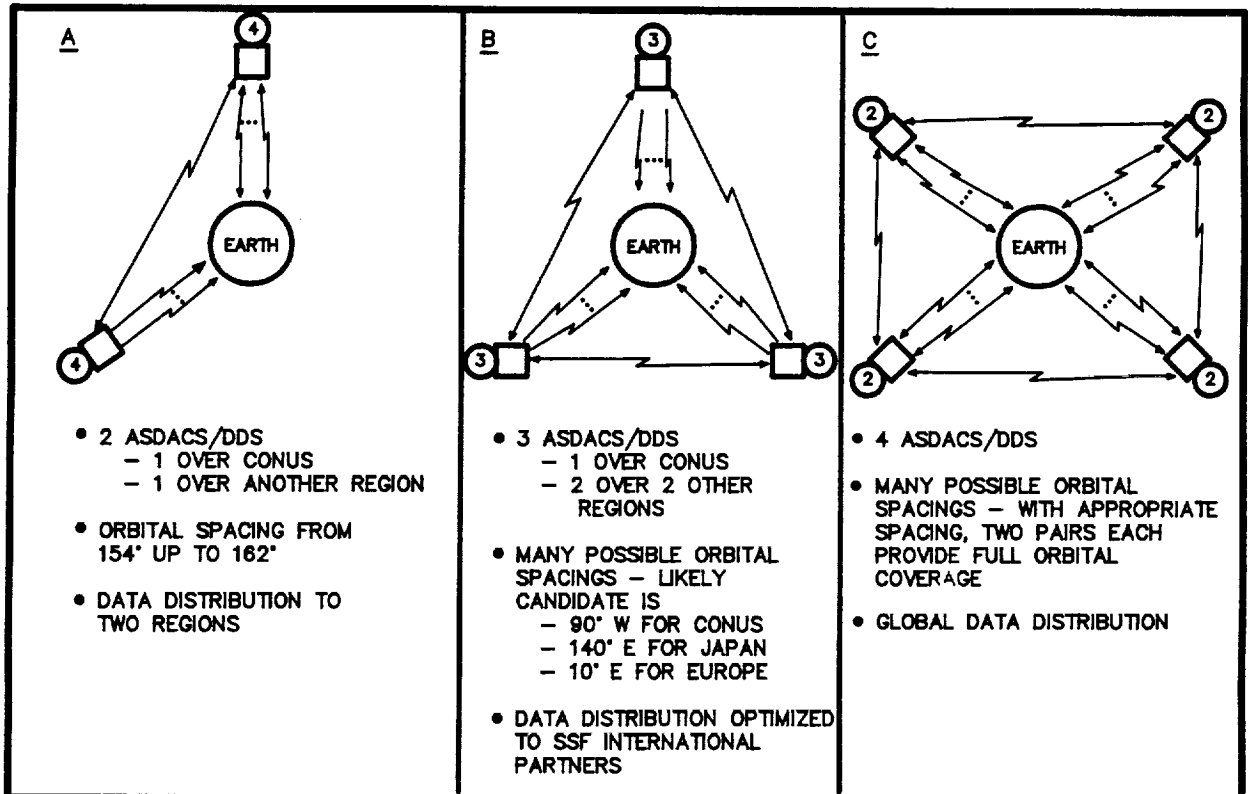
For the CONUS Gateway architecture denoted by A, the total ASDACS capability is contained in just two satellites. Thus each satellite is assumed to support four dedicated single access (DSA) services which are likely to be one of the primary drivers for satellite real estate. For the constellations with four satellites (B and C), each ASDACS supports only two DSA services.

Similarly, in the Global Network A architecture with two satellites, each supports four DSA services. In the three satellite constellation, three DSA services are supported by each satellite, and in the four satellite constellation, each supports only two DSA services.

## CONUS GATEWAY ARCHITECTURE



## GLOBAL NETWORK ARCHITECTURE



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Exhibit 4-2: Alternative Constellations

Exhibit 4-3 summarizes and compares some of the key features of architecture/constellation alternatives in various categories. These high level features, together with the subsystem and implementation considerations developed in the rest of Section 4 and in Section 5, form the basis for evaluating the alternatives.

Within the CONUS Gateway architectures, option A is attractive because it requires only two system crosslinks from a DDS to the ASDACS constellation. Options B and C require four system crosslinks from the DDSS to the ASDACS constellation and this is a big driver for DDS real estate. Option A also requires fewer ASDACS than B and C, but this is balanced somewhat by the fact that the option A ASDACS must support 4 DSA services while the ASDACS of options B and C support only 2.

Within the Global Network Architectures the capability of Option A to support global networks is limited because it has just two satellites in two different orbital slots. Option B is seen to be the most attractive of the Global Network Architectures because with 3 satellites in 3 different orbital slots it can support networking and data distribution to the U.S. and all its international partners in Space Station Freedom.



CHARACTERISTICS	CONUS GATEWAY			GLOBAL NETWORK		
SYSTEM ROBUSTNESS TO DDS FAILURE	A NO	B NO	C NO	A SOME	B SOME	C YES
FULL ORBITAL COVERAGE POSSIBLE AFTER ASDACS OR ASDACS/DDS FAILURE?	NO	YES	YES	NO	NEARLY	YES
NUMBER OF HANDOVERS PER ORBIT REQUIRED FOR FULL COVERAGE OF ORBITING PLATFORM	2	2	2	2	3	2
NUMBER OF SPACECRAFT IN CONSTELLATION	3	5	5	2	3	4
NUMBER OF DSA ANTENNAS PER ASDACS SPACECRAFT	4	2	2	4	3	2
POTENTIAL FOR DIRECT GLOBAL DISTRIBUTION OF DATA	NO	NO	NO	SOME	YES	YES
NUMBER OF SYSTEM ISLs	2	4	4	1	3	4
NUMBER OF ISLs PER SATELLITE	ASDACS 1 DDS 2	ASDACS 1 DDS 4	ASDACS 1 DDS 4	1	2	2
NUMBER OF UNIQUE SPACECRAFT IN CONSTELLATION	2	2	2	1	1	1
NETWORK CONTROL	CONUS CENTRALIZED	CONUS CENTRALIZED	CONUS CENTRALIZED	INT'L DISTRIBUTED	INT'L DISTRIBUTED	INT'L DISTRIBUTED

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Exhibit 4-3: Key Features of Architecture/Constellation Alternatives

## 4.2 DEFINITION OF KEY SUBSYSTEMS

Exhibit 4-4 defines and illustrates the subsystems, interfaces, and data flows for the CONUS Gateway and Global Network architectures. In the Gateway architecture, the key subsystems for the ASDACS and DDS spacecraft are as follows:

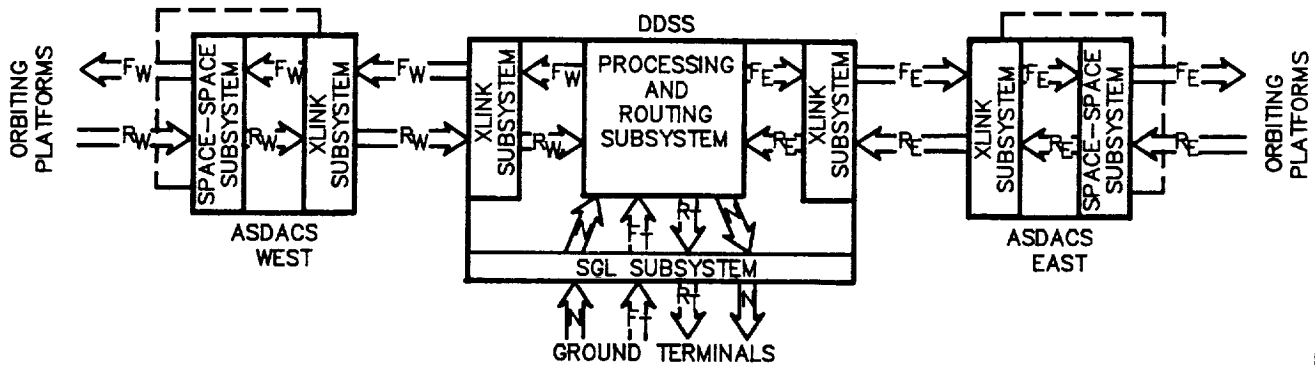
- ASDACS
  - Space-Space subsystem
  - Crosslink subsystem
- DDS
  - Crosslink subsystem
  - Processing and Routing subsystem
  - Space-Ground Link subsystem

In the Global Network architecture, the key subsystems for the combined ASDACS/DDSS spacecraft are as follows:

- ASDACS/DDSS
  - Space-Space subsystem
  - Processing and Routing subsystem
  - Crosslink subsystem
  - Space-Ground Link subsystem

For both the Gateway and the Global Network architectures, the traffic to and from all subsystems is developed from the top-level requirements identified in Section 2. Note that for the Global Network architecture, the traffic on most of the links is greater. More significantly, the required connectivities are far more complex. This significantly complicates network management and puts a major burden on the processing and routing subsystem of the satellites.

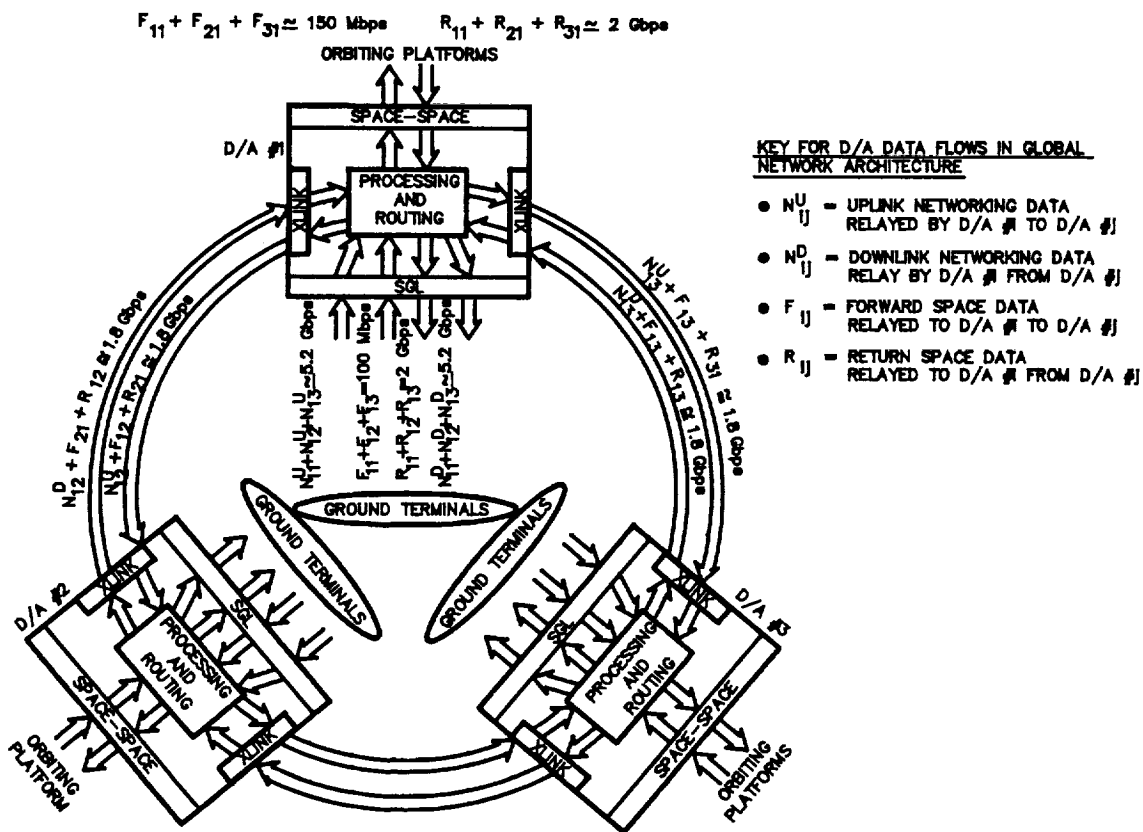
## CONUS GATEWAY ARCHITECTURE



### DATA TRAFFIC

$F_T$ :	FORWARD SPACE DATA (TOTAL ENVELOPE):	100 Mbps PEAK
$F_E$ :	FORWARD SPACE DATA (VIA EAST ASDACS):	100 Mbps PEAK
$F_W$ :	FORWARD SPACE DATA (VIA WEST ASDACS):	100 Mbps PEAK
$R_T$ :	RETURN SPACE DATA (TOTAL ENVELOPE):	2 Gbps PEAK
$R_E$ :	RETURN SPACE DATA (VIA EAST ASDACS):	1.3 Gbps PEAK
$R_W$ :	RETURN SPACE DATA (VIA WEST ASDACS):	1.3 Gbps PEAK
$N$ :	NETWORKING DATA (TOTAL):	4.2 Gbps PEAK

## GLOBAL NETWORK ARCHITECTURE



### KEY FOR D/A DATA FLOWS IN GLOBAL NETWORK ARCHITECTURE

- $N_{ij}^U$  = UPLINK NETWORKING DATA RELAYED BY D/A #1 TO D/A #j
- $N_{ij}^D$  = DOWNLINK NETWORKING DATA RELAY BY D/A #1 FROM D/A #j
- $F_{ij}$  = FORWARD SPACE DATA RELAYED TO D/A #1 TO D/A #j
- $R_{ij}$  = RETURN SPACE DATA RELAYED TO D/A #1 FROM D/A #j

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Exhibit 4-4: DDSS and ASDACS Connectivity and Interfaces

Exhibit 4-5 summarizes the allocation of functions to different subsystem. This functional allocation is then the driver for defining the detailed subsystem requirements and implementation alternatives in the next section.

KEY SUBSYSTEMS		APPLICABILITY TO ALTERNATIVE ARCHITECTURES	FUNCTIONAL ALLOCATION
ASDACS	SPACE-TO-SPACE	CONUS GATEWAY & GLOBAL NETWORK	DIRECT SUPPORT OF DUPLEX LINKS WITH ORBITING SPACE PLATFORMS IN LEO AND TRANSFER ORBITS
	CROSSLINK	CONUS GATEWAY ONLY	<ul style="list-style-type: none"> <li>• MUX (DEMUX) THE CROSSLINK COMPOSITE CHANNEL FROM (INTO) CHANNELS DEDICATED TO ORBITING PLATFORMS – E.G. SIMPLE FDM</li> <li>• DIRECT SUPPORT OF DUPLEX CROSSLINK WITH DDSS – CONTAINS FORWARD AND RETURN PLATFORM DATA</li> </ul>
DDSS	PROCESSING & ROUTING	CONUS GATEWAY & GLOBAL NETWORK	<ul style="list-style-type: none"> <li>• MUX (DEMUX) THE CROSSLINK COMPOSITE CHANNEL FROM (INTO) CHANNELS DEDICATED TO ORBITING PLATFORMS</li> <li>• BREAKDOWN (BUILD UP) CHANNELS FROM (TO) ORBITING PLATFORMS INTO (FROM) MULTIPLE CHANNELS WITH DIFFERENT END DESTINATIONS</li> </ul>
	SPACE-GROUND LINK	CONUS GATEWAY & GLOBAL NETWORK	DIRECT SUPPORT OF DUPLEX LINKS WITH MAJOR FACILITIES & END USERS – SUPPORTS FORWARD & RETURN PLATFORM DATA AND NETWORKING DATA
	CROSSLINK	CONUS GATEWAY	DIRECT SUPPORT OF DUPLEX CROSSLINK WITH DDSS – CONTAINS FORWARD & RETURN PLATFORM DATA
		GLOBAL NETWORK	DIRECT SUPPORT OF DUPLEX CROSSLINKS WITH THE OTHER TWO DDSS PAYLOADS – SUPPORTS FORWARD & RETURN PLATFORM DATA AND GLOBAL NETWORKING DATA

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Exhibit 4-5: Functional Allocation to ASDACS/DDSS Subsystems

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## SECTION 5

### SYSTEM DEFINITION

The entire system that is defined in this section is composed of the following elements:

- The DDSS communications payload
- The ASDACS communications payload
- Orbiting Platform communications payloads
- Major Facility ground terminals
- End User VSATs.

The scope of this definition activity includes high level trades arriving at antenna apertures, EIRPs, and frequencies, as well as implementation trades that guide how such front-end requirements can best be met for the implementations of all the subsystems of the DDSS and ASDACS.

## **5.1 APPROACH TO SYSTEM DEFINITION**

Exhibit 5-1 outlines the approach to system definition. The requirements, operations concept, and architectures, along with the ATDRSS heritage, form the basis for system definition. The approach is to consider first the DDSS and ASDACS subsystems that have interfaces with the Orbiting Platforms, Major Facilities and End Users. Defining these interfaces involves a variety of trades regarding the needed system resources versus user resources in closing a link at the required data rate. Thus in the process of defining the ASDACS Space-Space subsystem and DDSS SGL subsystem, the communications capabilities of the user terminals (Orbiting Platform, Major Facility GT and End User VSAT) are also defined. As part of this process, the channel structure of the communications link is also determined and this exerts a strong influence on the implementation of the DDSS Processing and Routing subsystem. The channel structure includes such areas as access protocols (i.e., DAMA, RMA) multi-user multiplexing (i.e., TDMA, FDMA modulation format, and channel coding. With the completion of the trades for the Processing and Routing subsystem and the Crosslink subsystem, the entire ASDACS and DDSS communications payload is defined along with the user community ground and orbiting terminals.





## 5.2 THE SPACE-SPACE SUBSYSTEM

The Space-Space subsystem is assigned to the ASDACS. Its primary function is to serve as the communications interface for the Orbiting Platform users. Three basic service types are offered by the Space-Space subsystem. These have been described in Section 3. These three service types are as follows:

- Dedicated Single Access (DSA) Service
- Dynamic Multiple Access (DMA) Service
- Message Transfer (MT) Service.

Providing for these services places requirements on both the user and the ASDACS communications payloads. Exhibit 5-2 summarizes the results of the trades that define the key parameters of the Orbiting Platform user and ASDACS payload. Five different users are listed: one DSA user, three classes of DMA users, and one MT user. The results are strongly driven by ATDRSS heritage in matters of user aperture, power, and frequency utilization. The need to limit the demands on user aperture and power is a prime determining factor, as are operational factors, such as the concept that certain user services (e.g., MT via a beacon) at low data rate must not require user antenna pointing, and therefore must be available to users with only omni antennas. Exhibit 5-3 illustrates the ASDACS Space-to-Space subsystem reference payload configuration that has been defined.

### 5.2.1 Dedicated Single Access Service

The primary driver for the aperture and power for DSA service is the return link. For 650 Mbps service, the trade between user and ASDACS resources results in a requirement for a 2 meter antenna and a 10 watt transmitter for the user, and for ASDACS, a G/T of about 30 dB/K consistent with a 3-5 meter antenna aperture and a 1000° K system noise temperature. The forward link EIRP value listed for the ASDACS is comparable to that planned for ATDRSS Ka-band service, and this value could support up to about 2 Mbps to a DSA user with a 2 meter antenna. Higher data rates than this, such as the 25 Mbps envisioned for Space Station Freedom would require a larger user antenna aperture or a greater ASDACS EIRP. In the reference configuration of the ASDACS Space-Space subsystem illustrated in Exhibit 5-3, the DSA service is provided via dedicated steerable antennas. A key driver for this implementation is the combined requirement of high gain and wide steering ability, which makes a multi-beam phased array or phased array-fed antenna unsuitable for this application. The number of single access antennas required is 2-4, depending upon the chosen ASDACS/DDSS architecture and constellation.

### 5.2.2 Dynamic Multiple Access Service

The DMA service envisioned will support return data rates from below 1 Kbps to 3 Mbps. Exhibit 5-2 illustrates the required user parameters for three users that cover this range of data rates. For the same user set, the range of forward data rates is from 1 Kbps to 100 Kbps. The return link G/T for the

CLASS OF ORBITING PLATFORM	ORBITING PLATFORM COMM PAYLOAD PARAMETERS	ASDACS COMM PAYLOAD PARAMETERS
DSA USER <ul style="list-style-type: none"> <li>• 2 Mbps FWD</li> <li>• 650 Mbps RTN</li> </ul>	<ul style="list-style-type: none"> <li>• 2 METER ANTENNA (LARGER FOR HIGHER FWD DATA RATE)</li> <li>• 10 WATT XMIT POWER</li> </ul>	<ul style="list-style-type: none"> <li>• Ka-BAND FREQUENCY</li> <li>• EIRP = 56 dBw</li> <li>• G/T <math>\approx</math> 30 dB/K</li> </ul>
GENERIC LARGE DMA USER <ul style="list-style-type: none"> <li>• <math>\geq</math> 100 Kbps</li> <li>• 3 Mbps RTN</li> </ul>	<ul style="list-style-type: none"> <li>• 0.75 METER ANTENNA</li> <li>• 4 WATT XMIT POWER</li> </ul>	<ul style="list-style-type: none"> <li>• S-BAND FREQUENCY</li> <li>• EIRP <math>\approx</math> 43 dBw; 8 dB INCREASE RELATIVE TO PLANNED ATRSS</li> <li>• G/T <math>\approx</math> 9 dB/K; SAME AS PLANNED ATRSS</li> </ul>
GENERIC MEDIUM SIZED DMA USER <ul style="list-style-type: none"> <li>• 10 Kbps FWD</li> <li>• 50 Kbps RTN</li> </ul>	<ul style="list-style-type: none"> <li>• ELECTRONICALLY SWITCHED SPHERICAL ARRAY (ESSA) ANTENNA W/ 8 dB GAIN</li> <li>• 4 WATT XMIT POWER</li> </ul>	
GENERIC SMALL DMA USER: <ul style="list-style-type: none"> <li>• 1 Kps FWD</li> <li>• 10 Kbps RTN</li> </ul>	<ul style="list-style-type: none"> <li>• OMNI ANTENNA</li> <li>• 4 WATT XMIT POWER</li> </ul>	
GENERIC USER OF BEACON (i.e., MT SERVICE) <ul style="list-style-type: none"> <li>• 125 bps FWD/RTN</li> </ul>	<ul style="list-style-type: none"> <li>• OMNI ANTENNA</li> <li>• 4 WATT XMIT POWER</li> </ul>	<ul style="list-style-type: none"> <li>• S-BAND FREQUENCY</li> <li>• 10' CONICAL BEAM</li> <li>• EIRP <math>\approx</math> 30 dBw</li> <li>• G/T <math>\approx</math> -11.3 dB/K</li> </ul>

Exhibit 5-2: Summary Overview of ASDACS Space-Space Subsystem Trades

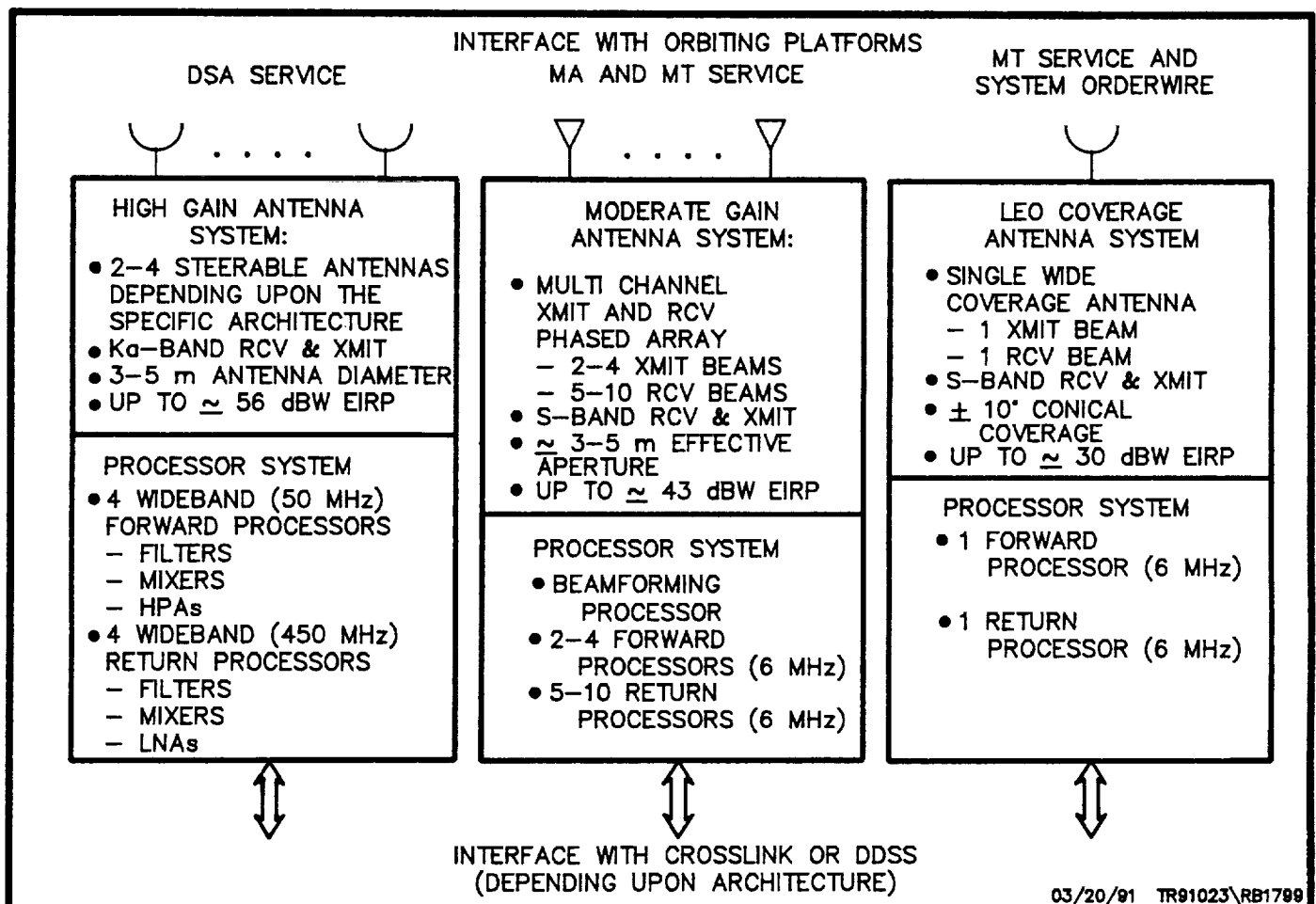


Exhibit 5-3: ASDACS Space-to-Space Reference Configuration

ASDACS DMA service is assumed to be 9 dB/K which is the same as is currently planned for ATDRSS [12]. The 3 Mbps user needs only a 0.75 meter antenna to make the link with 4 watts of transmit power. The 50 Kbps user with the same power requires an antenna with about 8 dB gain which could be provided by an Electronically Switched Spherical Array (ESSA) antenna envisioned for midsized space platforms [14]. Finally, the 10 Kbps user would require only an omni antenna and 4 watts of power. The forward DMA service with the same user population could support 100 Kbps, 10 Kbps and 1 Kbps respectively. This service represents an evolution from ATDRSS in that a forward EIRP of 43 dBW is assumed, which is a 6 dB increase relative that planned for ATDRSS [12]. Furthermore, the dynamic time sharing envisioned for this service is a significant evolution from ATDRSS. Since the implementation for the DMA service is envisioned as a phased array, it can be capable of rapid steering on the timescale of a 1 msec or less. Thus, it is possible to timeshare a single forward DMA service among many users. For example, several users of a single 10 Kbps beam could each be allocated a 1 sec time slot every 10 seconds. Each user would therefore be supported by an equivalent 1 Kbps link which would have the feel of a continuous contact. Thus, in this manner, the imbalance between forward and return MA service in ATDRSS could be eliminated in ASDACS.

### **5.2.3 Message Transfer Service**

MT service would be provided via a 10° conical beacon at S-band covering all LEO orbits. Such a service is currently envisioned as an option for ATDRSS. For ASDACS, we have assumed a 30 dBW EIRP which is consistent with about 15 dB gain and less than 30 watts of transmit power. Such a beacon could provide a continuous 125 bps service supporting both system messages and short user directed messages to all users with only omni gain antennas. A 125 bps service could also be provided on the return link.

## **5.3 THE SPACE-GROUND LINK (SGL) TRADES**

Exhibit 5-4 summarizes the results and key drivers for the definition of the SGL subsystems for the DDSS, and Major Facility and End User ground terminals. The SGL subsystem is composed of the three antennas as illustrated in Exhibit 5-5. These are as follows:

- High gain transmit antenna
- High gain receive antenna
- Low gain duplex antenna.

Together, these antennas support all the SGL subsystem requirements for the DDSS.

### **5.3.1 High Gain Transmit Antenna**

The high gain transmit antenna has a nominal 300 Mbps interface with the Major Facility ground terminals on both the uplink and downlink. Ka-band is the frequency of choice to accommodate the multi-Gbps envelope requirement. A narrow beam of 0.3° on the downlink is driven by the need to limit the required

USERS AND KEY LINK FEATURES	EARTH TERMINAL CHARACTERISTICS	DDSS CHARACTERISTICS	COMMENTS
<b>MAJOR FACILITIES</b> <ul style="list-style-type: none"> <li>- 300 Mbps DOWNLINK FOR RETURN SPACE DATA AND FOR NETWORKING WITH OTHER MAJOR FACILITIES</li> <li>- 300 Mbps UPLINKS FOR NETWORKING WITH OTHER MAJOR FACILITIES AND WITH END USERS</li> <li>- TDMA ON UPLINKS AND DOWNLINKS</li> </ul>	<ul style="list-style-type: none"> <li>• 5 METER ANTENNA APERTURE</li> <li>• 10 - 100 WATT TRANSMIT POWER ADAPTIVE TO RAIN DEGRADATION</li> </ul>	<ul style="list-style-type: none"> <li>• 10 MULTIPLE FIXED BEAMS @ 0.3° COVERING ALL MAJOR FACILITY LOCATIONS</li> <li>• MULTIPLE STEERED TRANSMIT BEAMS AT 0.3° COVERING ALL MAJOR FACILITIES</li> <li>• 2 - 20 W PER BEAM; ADAPTIVE TO RAIN DEGRADATION</li> </ul>	<ul style="list-style-type: none"> <li>• 300 MBPS TDMA ON U/L AND D/L DRIVEN BY EFFICIENCY AND SIMPLICITY</li> <li>• 0.3° DDS TRANSMIT BEAM IS DRIVEN BY NEED TO LIMIT DDS POWER</li> <li>• Ka-BAND FREQUENCY DRIVEN BY THE UP TO 4 Gbps DOWNLINK ENVELOPE FOR RETURN SPACE DATA AND NETWORKING OF MAJOR FACILITIES</li> </ul>
<b>END USER VSATs</b> <ul style="list-style-type: none"> <li>- 150 Mbps TDMA DOWNLINKS FOR NETWORKING WITH MAJOR FACILITIES AND END USERS AND FOR RETURN SPACE DATA</li> <li>- UP TO 128 Kbps FDMA/SCPC UPLINKS FOR NETWORKING WITH MAJOR FACILITIES AND END USERS</li> </ul>	<ul style="list-style-type: none"> <li>• 2 METER ANTENNA APERTURE</li> <li>• ≤ 5 WATT TRANSMIT POWER: 10 dB OF RAIN MARGIN @ 16 Kbps</li> </ul>	<ul style="list-style-type: none"> <li>• SHAPED CONUS COVERAGE RECEIVE BEAM</li> <li>• MULTIPLE STEERED TRANSMIT BEAMS AT 0.3° COVERING ALL OF CONUS</li> <li>• 2 - 20 W PER BEAM; ADAPTIVE TO RAIN DEGRADATION</li> </ul>	<ul style="list-style-type: none"> <li>• VSAT AS LARGE AS 2 M AND 0.3° DDS XMIT BEAM IS NEEDED TO LIMIT DDS POWER FOR DOWNLINK</li> <li>• WITH A 2 M VSAT APERTURE, ONLY A MODERATE GAIN CONUS DDS ANTENNA IS NEEDED ON UPLINK</li> <li>• Ka-BAND FREQUENCY DRIVEN BY 2 Gbps NETWORKING REQUIREMENT W/MAJOR FACILITIES; Ku-BAND WOULD BE PREFERRED W/O THIS DRIVER</li> </ul>

Exhibit 5-4: Summary Overview of DDSS SGL Subsystem Trades

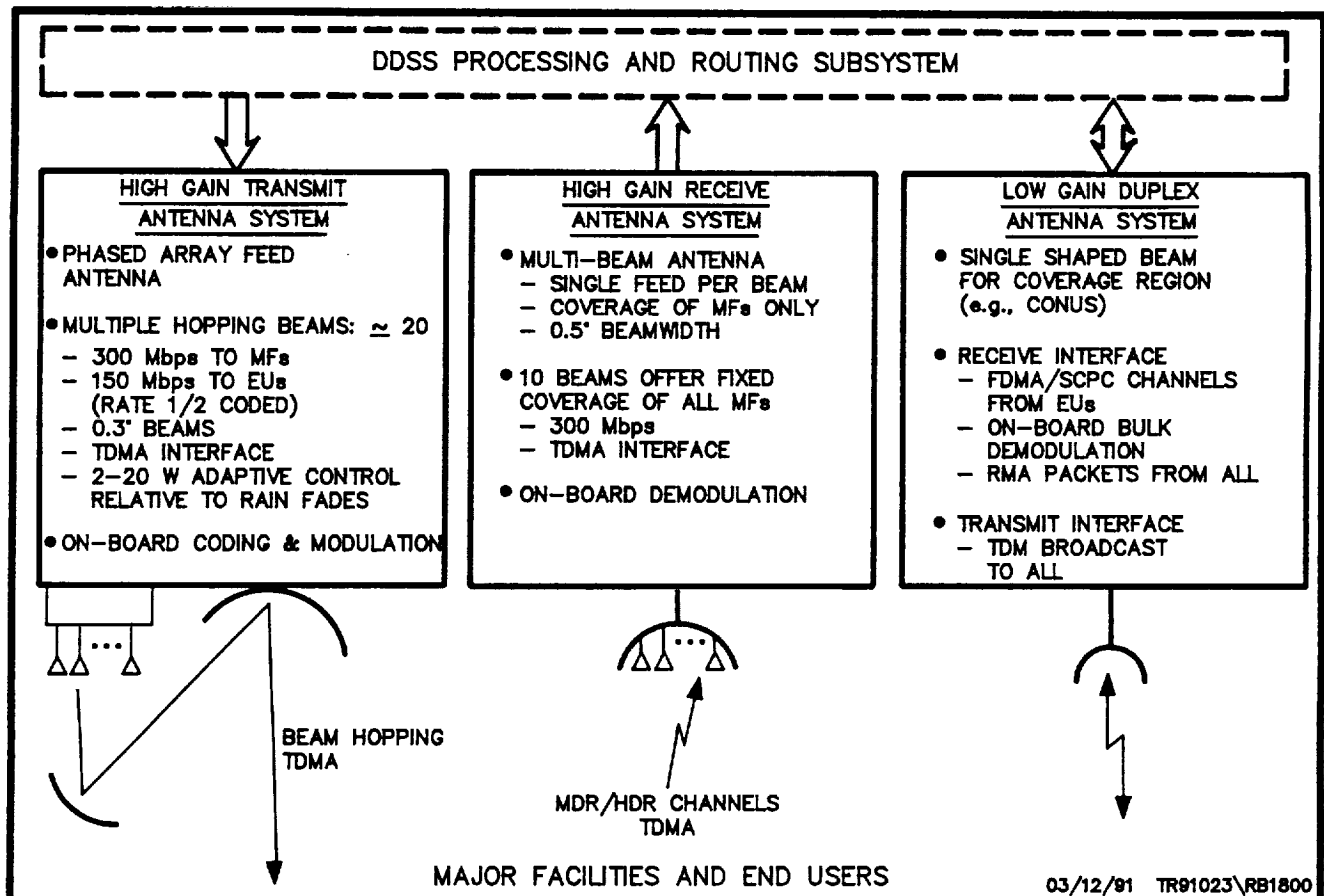


Exhibit 5-5: DDSS SGL Subsystem Reference Configuration

satellite power. Each beam is supported by as little as 2 watts of power, but the phased array fed antenna can adapt to rain fades and provide an additional 10 dB of power for selected beam dwells. A 5 meter antenna aperture is chosen as the baseline for the Major Facility ground terminals. Up to roughly 600 Mbps could be transmitted to each major facility by assigning two 300 Mbps beams.

The high gain antenna has a 150 Mbps interface with End User VSATs. This is supported by the same transmit beams that serve the Major Facility ground terminals. In order to conserve satellite power, the data is assumed to be rate 1/2 coded, and a VSAT antenna size of 2 meters is selected. This is an optimum choice because with the coding, the channel bandwidth of the End User data streams are equal to those of the 300 Mbps Major Facility data streams. Coding, together with the lower data rate, requires about 8 dB less transmit power, but this is exactly compensated for by the lower gain of the VSAT antenna. Thus the beams of the high gain antenna system have the same characteristics for both Major Facilities and End Users, so that the common system described here can efficiently meet both needs.

### **5.3.2 High Gain Receive Antenna**

The high gain receive antenna provides a 300 Mbps uplink with the Major Facilities. Because the End Users have no need to transmit very large amounts of data, they do not have an interface with the high gain receive antenna. Since this system serves only Major Facilities, and since Major Facilities tend to be clustered in distinct geographical areas, a relatively simple high gain receive antenna implementation can be considered. Ten fixed beams in selected areas could encompass all of NASA's centers and other sites that will contain the archives, processing and other infrastructure for managing space data. With their 5 meter antennas, the Major Facility ground terminals will require only about 10 watts of transmit power to support a 300 Mbps data stream into the 0.3° receive beamwidths assumed for the DDSS high gain receive antenna. Options of operating at 150 Mbps rate 1/2 coded and/or using a 100 watt transmitter will provide up to 18 dB of rain margin.

### **5.3.3 Low Gain Duplex Antenna**

The low gain duplex antenna creates a transmit and receive beam over its entire coverage area, such as CONUS. It serves as the receive interface for all End Users. For consistency with VSAT concepts, the uplink channels are assumed to be demand assigned FDMA/SCPC, supporting data rates up to 128 Kbps. Less than 5 watts of transmit power will provide a large rain margin for 16 Kbps data rates. For higher data rates, only a small margin would be provided.

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## 5.4 PROCESSING AND ROUTING SUBSYSTEM

The DDSS processing and routing subsystem has an interface with all the users of the DDSS as illustrated in Exhibit 5-6. The choice of the implementation of the processing and routing system is strongly driven by the requirements and constraints of its users, including such parameters as envelope data rate, modulation format, channel multiplexing and access protocols. The key user interfaces are as follows:

- Interface with Major Facilities: 300 Mbps on both the uplink and the downlink with TDMA allocation of multiple beams
- Interface with End User VSATs: 150 Mbps hopping beams on the downlink and many (1000s) of FDMA/SCPC low data rate channels on the uplink; demand assigned access on both links
- Interface with Orbiting Platforms: Several channels in forward and return directions with a wide range of data rates and formats; mostly dedicated, but some time-shared channels.

In consideration of alternative switching implementations, it is important to strike the proper balance between switching flexibility and complexity that accounts for the requirements and constraints of its users while it avoids needless complexity. That is, the switching implementation should provide the needed flexibility to its users, while it minimizes overall processing requirements. The following is a list of alternative switching implementations for the processing and routing subsystem:

- Microwave space switch matrix
- Baseband space switch matrix (w/o memory)
- Baseband time-space-time switch (w/memory)
- Fast packet switching
- Datagram packet switching.

For a given throughput, the two top most alternatives embody the least system complexity, but offer the least user flexibility. Thus, these are most suitable for switching high data traffic among a few nodes such as the Major Facilities. At the opposite end, datagram packet switching offers the most flexibility but it is inefficient and not desirable or feasible for high data rate links. Rather, it is most suitable for low data rate traffic on the random access channel.



INTERFACE WITH ORBITING PLATFORMS

- FLEXIBLE INTERFACE TO MINIMIZE IMPACT ON PLATFORMS
- WIDE RANGE OF DATA RATES & FORMATS
- CCSDS STANDARDS

INTERFACE WITH XLINK (60 GHz)

- CONUS GATEWAY ARCHITECTURE
  - FDM COMPOSITE OF ALL SPACE DATA CHANNELS ON FWD AND RTN
- GLOBAL NETWORK ARCHITECTURE
  - 300/600 Mbps DUPLEX TDM CHANNELS

INTERFACE WITH XLINK (OPTICAL)

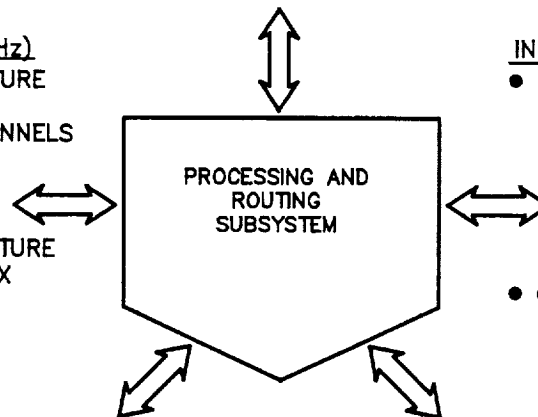
- CONUS GATEWAY ARCHITECTURE
  - TWO 300/600 Mbps RTN CHANNELS
- FDM COMPOSITE OF OTHER CHANNELS ON FWD & RTN via SUBCARRIER IM
- GLOBAL NETWORK ARCHITECTURE
  - 300/600 Mbps DUPLEX TDM CHANNELS

INTERFACE WITH MAJOR FACILITIES

- 300 Mbps TDMA FOR U/L AND D/L CHANNELS

VSAT COMPATIBLE INTERFACE WITH END USERS

- FDMA/SCPC LDR U/L CHANNELS
- 150 Mbps TDMA D/L CHANNELS (RATE 1/2 ENCODED)



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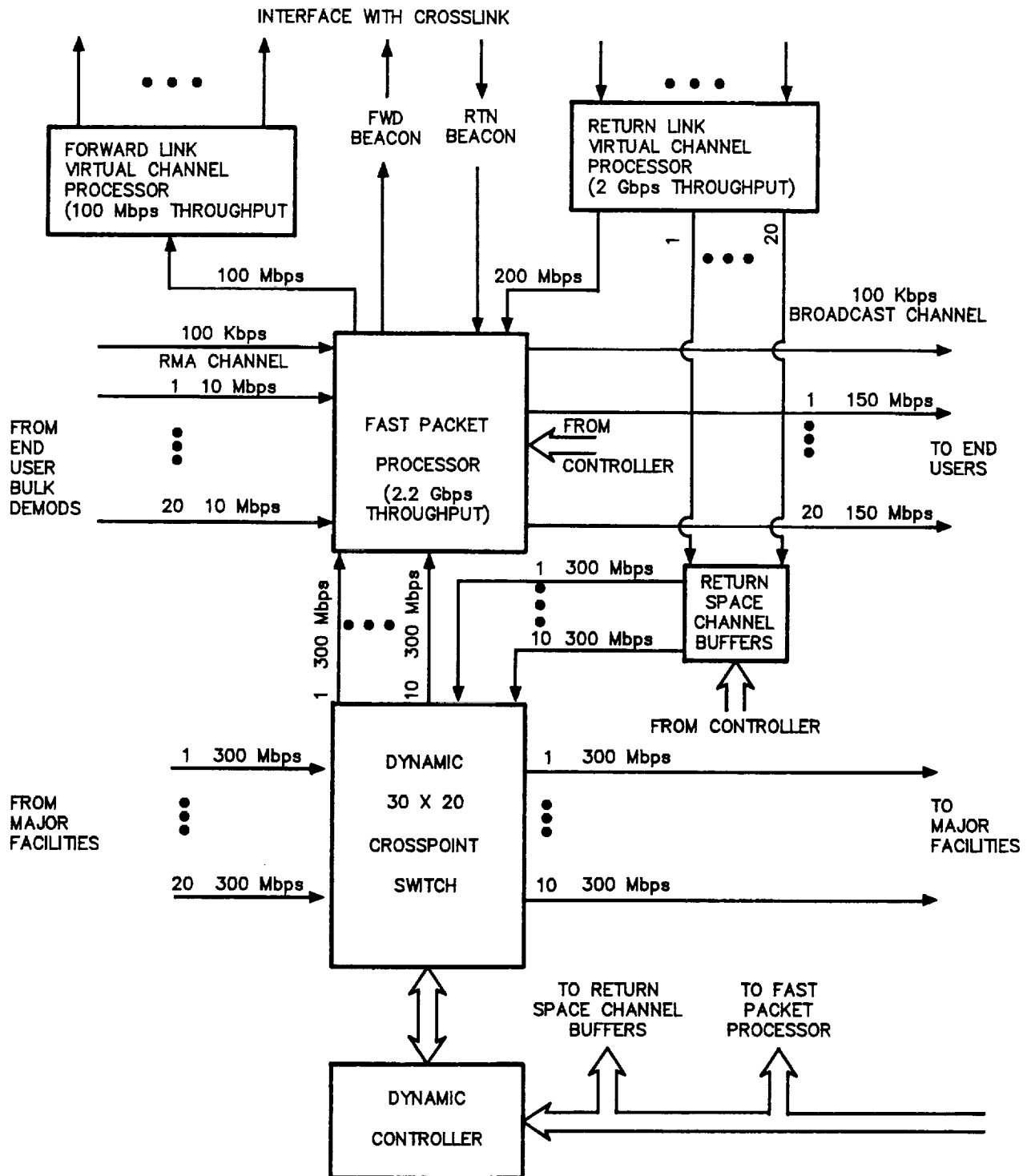
Exhibit 5-6: Scope of DDSS Processing Routing Requirements

Exhibit 5-7 illustrates the chosen implementation for the DDSS processing and routing system for the CONUS Gateway architecture. The key features are as follows:

- **Dynamic Crosspoint Switch:** this switch provides high data rate connectivity directly between all major facilities. This by far the least complex implementation for switching very high data rate streams between a small number of ground terminals.
- **Fast Packet Processor:** This provides the needed flexibility for switching the 150 Mbps streams directed at the End User VSATs. Unlike datagram packet switching which is suited only for short messages at low to moderate data rate, fast packet switching protocols require a minimum of overhead and can operate at high data rate of 150 Mbps and beyond.
- **Virtual Channel Processors:** the forward and return virtual channel processors are essentially fast packet switching devices for the Space-Space data channels which we assume to utilize the CCSDS data protocols. The return space channel buffers are required to synchronize the returning space data to the TDMA timing scheme of the dynamic crosspoint switch.
- **Dynamic Controller:** the system illustrated in Exhibit 5-7 requires a controller to ensure that all the switching components are configured at the proper timing epochs.

The processing and routing system for the Global Network architecture is similar, but the crosspoint switch is of a higher dimension and it has a direct interface to the crosslink system.

## CONUS GATEWAY ARCHITECTURE



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Exhibit 5-7: DDSS Processing and Routing Subsystem

## **5.5 CROSSLINK SUBSYSTEM**

Exhibit 5-8 summarizes the key features of the DDSS crosslink subsystem for the CONUS Gateway and Global Network architectures. The parameters for both optical and 60 GHz implementation are included. In general, the requirements for the Gateway architecture are considerably less for two reasons: the Gateway architecture crosslink supports a lower data rate envelope and it also spans a shorter GEO arc. Together, these two factors account for almost a 10 dB difference in required power. For both the 60 GHz and optical alternatives, the optimum design is typically to choose the largest reasonable receive and transmit apertures and to size the transmitter power sufficient to complete the link. For optical links, the practical maximum aperture chosen is 20 cm and for 60 GHz a 2 meter aperture is chosen.

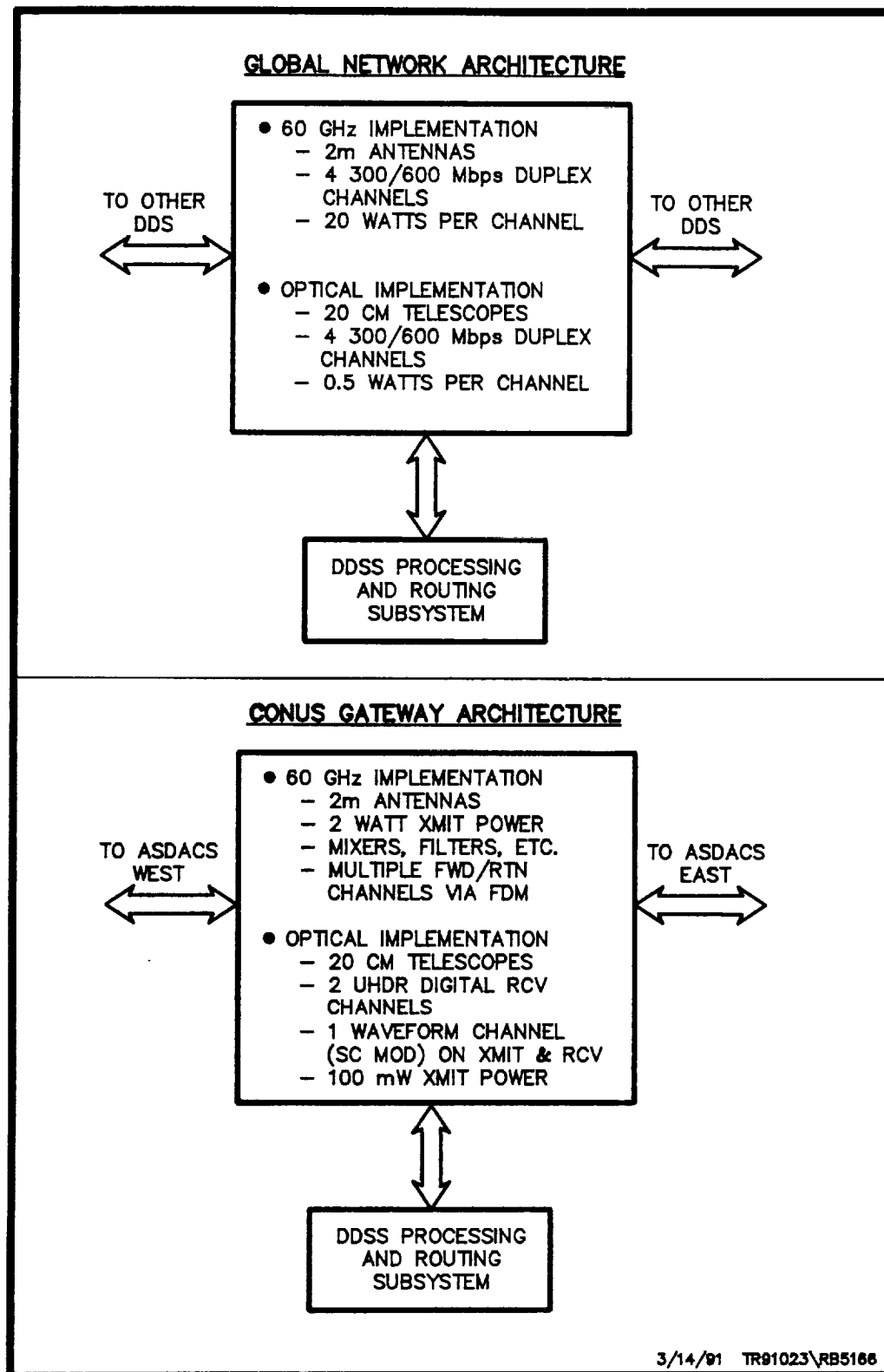


Exhibit 5-8: DDSS Xlink Subsystem Reference Configuration

## 5.6 TOTAL COMMUNICATIONS PAYLOAD

In this section the features of the communications payloads of the DDSS and ASDACS are summarized.

### 5.6.1 Payload of the CONUS Gateway Architecture

Exhibit 5-9 summarizes the key features of the communications payload for the ASDACS and the DDSS. The ASDACS payload is composed of the Space-to-Space subsystem and the Crosslink subsystem. Since we have chosen to load all the processing complexity on the DDSS, the ASDACS payload is a simple frequency translation repeater. A 60 GHz implementation is chosen since it is most suited to this implementation. The DDSS contains the Crosslink subsystem (providing a link to two ASDACS), the SGL subsystem and the Processing and Routing subsystem. Exhibit 5-10 illustrates the DDSS payload concept and an example satellite configuration.

#### ASDACS (2 S/C)

- Space-to-Space Subsystem
  - 1.3 Gbps Receive Capacity
  - 4 DSA Antennas
  - Large S-Band Phased Array For DMA Service
- XLINK Subsystem
  - 1.3 Gbps XMIT Capacity
  - 100 Mbps Receive
  - 60 GHz or Optical Implementation
  - FDM Composite of Distinct Channels to Orbiting Platforms

#### DDSS (1 S/C)

- SGL Subsystem
  - Conus Coverage XMIT/RCV Antenna
  - 10 Fixed 0.3° Receive Beams
  - 20 Scanning 0.3° Transmit Beam
  - ~ 4/6 bps RCV/XMIT Capacity
  - Demods/Mods
- XLINK Subsystems (2)
  - 1.3 Gbps Receive Capacity
  - 100 Mbps XMIT
  - 60 GHz or Optical Implementation
  - FDM Composite
  - Demods/Mods
- Processing and Routing Subsystem
  - Up to 6 Gbps Throughput
  - TDMA Circuit Switching for Simple Routing
  - Fast Packet Switching for More Complex Routing

Exhibit 5-9: Communication Payload For CONUS Gateway Architecture

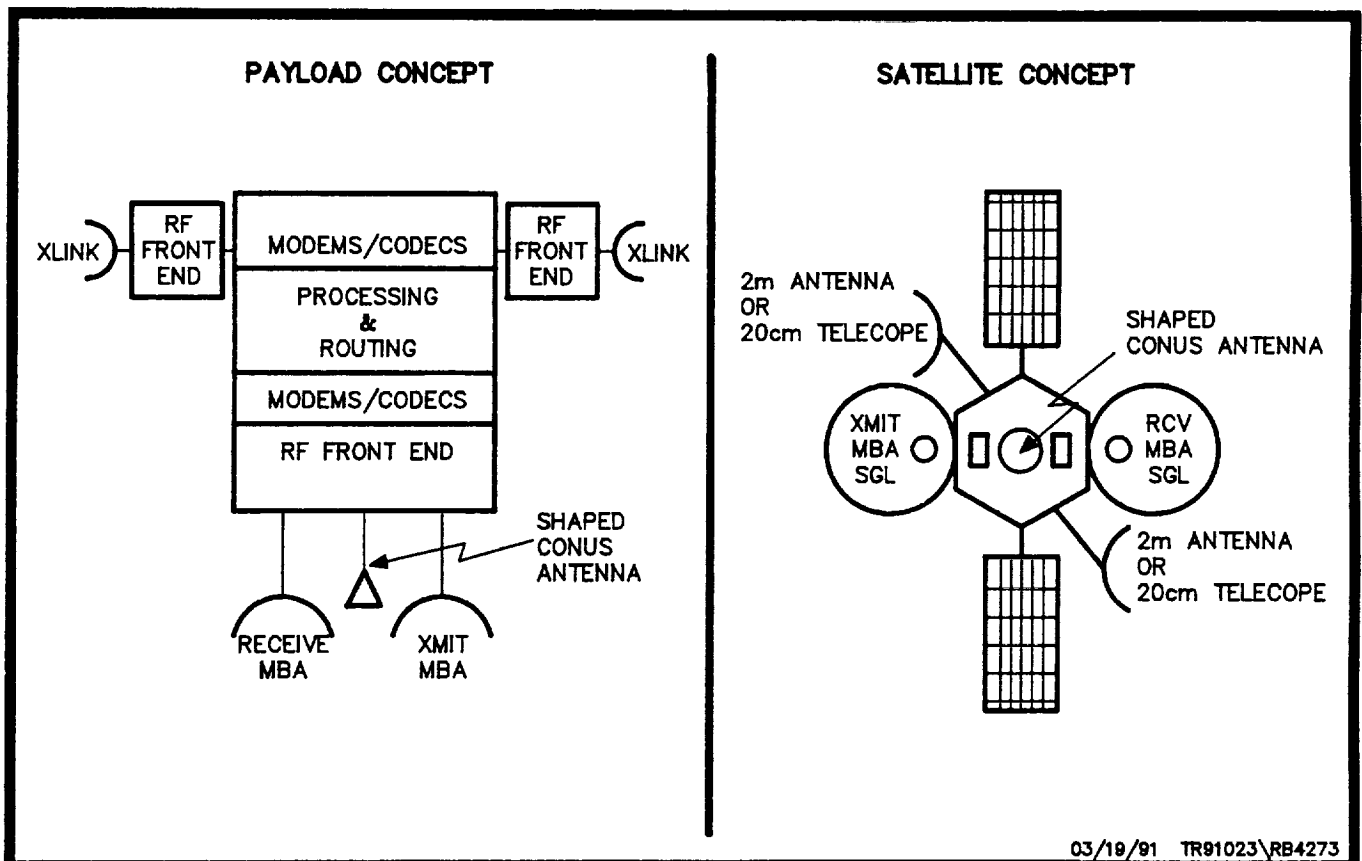


Exhibit 5-10: Operational DDSS For CONUS Gateway Architecture

### **5.6.2 Payload of the Global Network Architecture**

Exhibit 5-11 summarizes the key features of the communications payload of the combined ASDACS/DDSS of the Global Network architecture. This payload is comprised of the Space-to Space, Crosslink, SGL and Processing and Routing subsystems. Exhibit 5-12 illustrates a logical diagram of the payload as well as a satellite concept. Even at this level it is clear that so many functions are combined in the satellite so that its complexity is high. Furthermore, all the real estate requirements for large antenna apertures will make the packaging of this satellite a difficult and challenging undertaking.

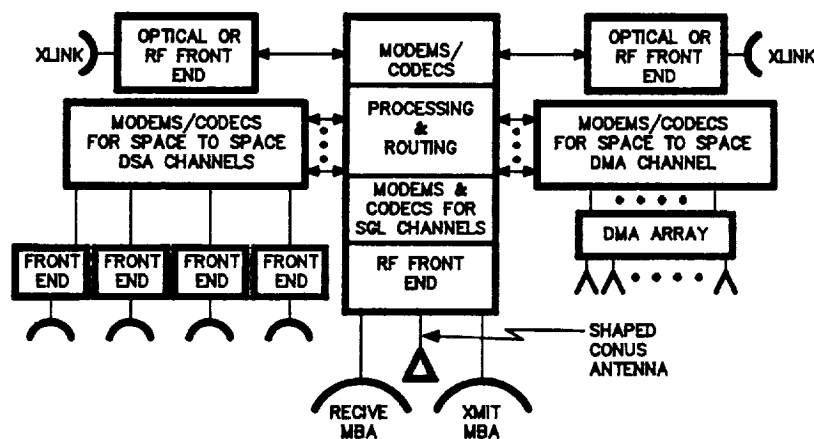


### COMBINED ASDACS/DDSS (3 S/C)

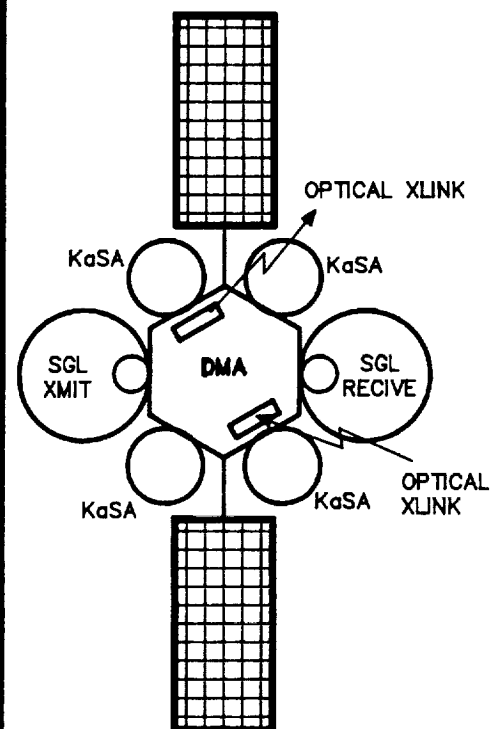
- Space-to-Space Subsystem
  - Same as CONUS Gateway, Plus
  - Demods, Mods For The Space-Space Channels
- XLINK Subsystems (2)
  - 1.8 Gbps XMIT Receive Capacity
  - 300/600 Mbps Channels
  - Optical or 60 GHz Implementation
- SGL Subsystem
  - Conus Coverage XMIT/RCV Antenna
  - 10 Fixed 0.3° Receive Beams
  - 20 Scanning 0.3° Transmit Beams
  - $\approx 5/7$  Gbps RCV/XMIT Capacity
- Processing And Routing System
  - $\approx 7$  Gbps Throughput
  - TDMA Circuit Switching
  - Fast Packet Switching

Exhibit 5-11: Communication Payload For Global Network Architecture

### PAYLOAD CONCEPT



### SATELLITE CONCEPT



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Exhibit 5-12: Operational ASDCS/DDSS For Global Network Architecture

## **5.7 PAYLOAD MASS AND POWER SUMMARIES**

Exhibits 5-13 and 5-14 summarize the payload mass and power estimation for the CONUS Gateway and Global Network architectures, respectively. The estimation methodology is summarized in Section 8. The payload of the CONUS Gateway satellite is large, but its mass and power envelopes are comparable to payloads of large communications satellites that have been built or envisioned. In particular, the Gateway payload mass is comparable to that of INTELSAT VI, and its power is comparable to INTELSAT VII. Further, both its power and mass are consistent with the capabilities envisioned for the GE 7000 series communications satellite bus.

In contrast, the payload mass and power of the Global Network architecture are well outside the bounds envisioned for even very large communications satellites. Although, a combined ASDACS/DDSS is an interesting concept, its development would pose a far greater technology risk than the Gateway satellite.

<b>ASDACS (2 S/C Required)</b>	<b>Mass</b>	<b>Power</b>	<b>Basis of Estimate</b>
• Space-to-Space System	735 LBS	670 Watts	(15)
• Crosslink Subsystem	150 LBS	270 Watts	(15), (16)
<b>Total</b>	<b>885 LBS</b>	<b>940 Watts</b>	<b>----</b>

<b>DDS (1 Required)</b>	<b>Mass</b>	<b>Power</b>	<b>Basis of Estimate</b>
• SGL subsystem	990 LBS	2330 Watts	(17), (18),
• Crosslink Subsystem (X2) (With Demods/Mods for Space Channels)	350 LBS	485 Watts	(20)
• Processing and Routing Subsystem	150 LBS	670 Watts	(15), (16)
			(19), (21)
<b>Total</b>	<b>1490 LBS</b>	<b>3485 Watts</b>	<b>----</b>

Exhibit 5-13: CONUS Gateway Architecture Communications Payload Mass and Power Estimates

<b>ADSACS/DDSS (3 S/C Required)</b>	<b>Mass</b>	<b>Power</b>	<b>Basis of Estimate</b>
• Space-to-Space Subsystem (With Demods/Mods for Space Channels)	720 LBS	800 Watts	(15)
• Crosslink Subsystems (X2)			
• SGL Subsystem	370 LBS	1265 Watts	(15), (16)
• Processing and Routing Subsystem	990 LBS	2330 Watts	(17), (18),
	225 LBS	1020 Watts	(20)
			(19), (21)
<b>Totals</b>	<b>2305 LBS</b>	<b>5415 Watts</b>	<b>----</b>

Exhibit 5-14: Global Network Architecture Communications Payload Mass and Power Estimates

**Data Base:** (15) ATDRSS Phase A studies; (16) ATDRSS Xlink study; (17) ATDRSS MBA study; (18) Ball aerospace antenna; (19) GSFC microelectronics branch prototyping of CCSDS processors ; (20) TRW bulk demodulation estimates; (21) COMSAT packet switching study

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**SECTION 6****TRANSITION TO THE DDSS/ASDACS ARCHITECTURE**

According to current ATDRSS plans, the ATDRSS era will commence in 1997 with the first ATDRSS launch, and will last for approximately 15 years, or until about the year 2012. This section explores the timing and alternatives for a gradual transition from the ATDRSS to the follow-on DDSS/ASDACS system.

## **6.1 SYSTEM EVOLUTION**

The transition from the ATDRSS to the CONUS Gateway Architecture involves the major changes in a number of areas. These include:

- Changeover to a new system architecture and orbital constellation
- The development of new communications payloads and satellites
- The insertion of new technologies into the communications payloads
- The introduction of new operations concepts concerning service provision, assurance and scheduling

The two architectures are illustrated in Exhibits 6-1 and 6-2, respectively. The baseline ATDRSS is comprised of four operational satellites which all have line-of-sight to the ATDRSS ground terminals at the White Sands complex. In this architecture, all SGL connections to the satellites are via the White Sands complex. In contrast, in the CONUS Gateway architecture there are many SGL connections to the Major Facilities and thousands of connections to VSATs widely distributed over CONUS. Furthermore, neither of the ASDACS satellites have line of sight to White Sands, but are instead connected to White Sands and other CONUS locations via crosslinks.

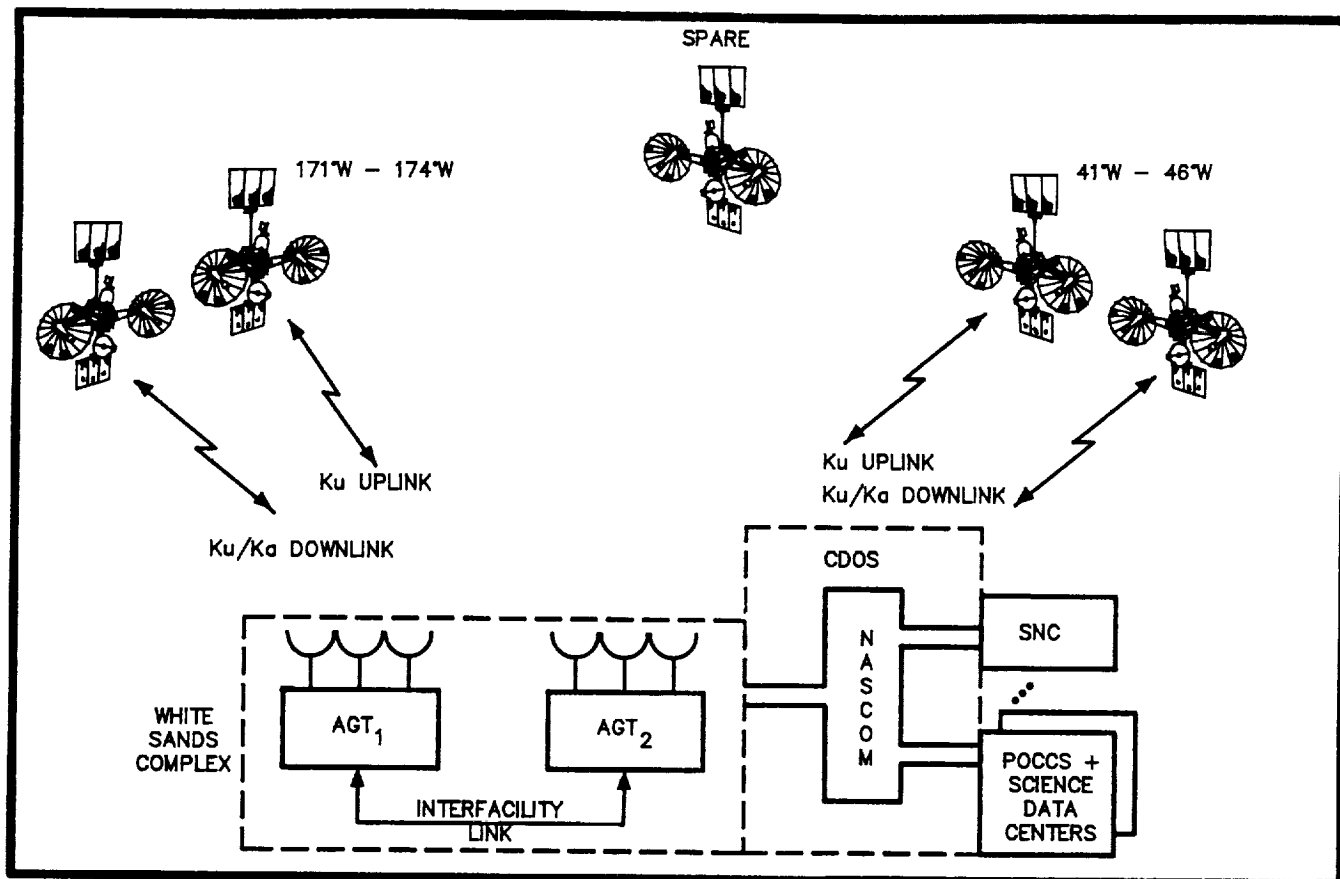


Exhibit 6-1: Baseline ATRRSS

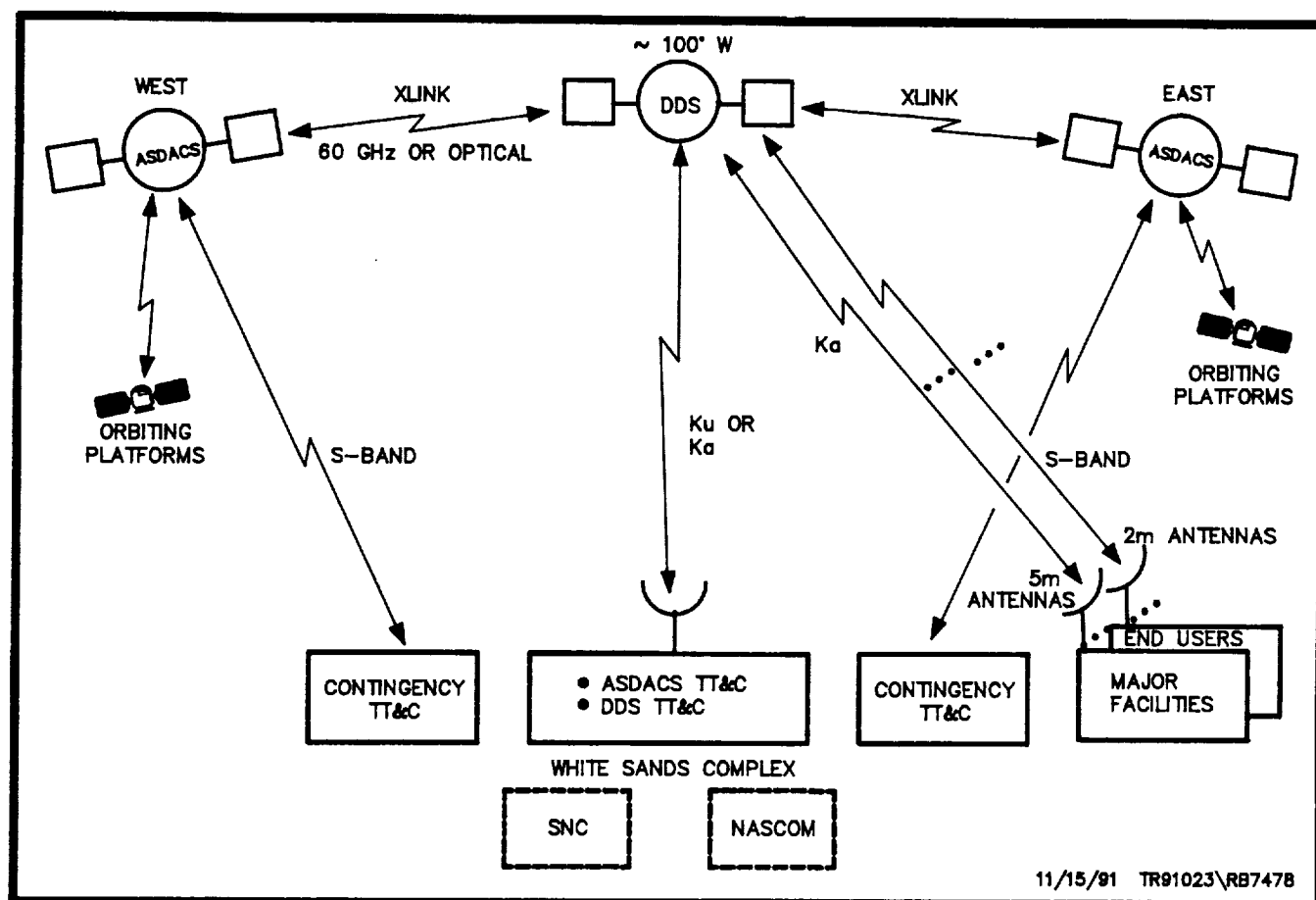


Exhibit 6-2: ASDACS and DDS 2010+ - CONUS Gateway

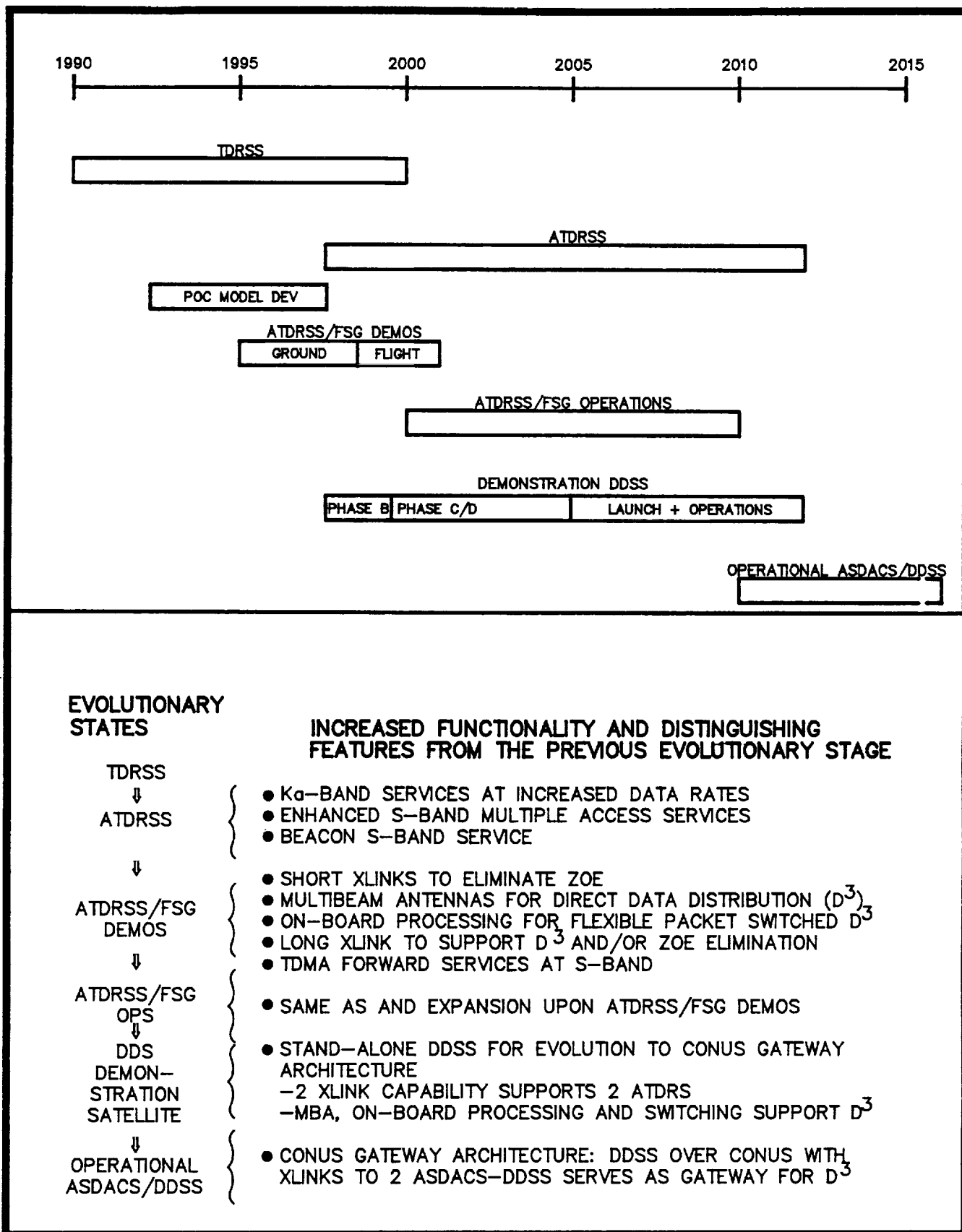
With the introduction of so many new features, it will be important to plan the transition so that the new features can be demonstrated prior to operations, and these features can be introduced in a gradual manner. Exhibit 6-3 illustrates the various time frames concerning the evolution of NASA's space network from TDRSS, through ATDRSS, and finally to the DDSS/ASDACS system. Within this timeline, it is seen that the ATDRSS Future Service Growth (FSG) module [12] can play a key role in supporting an orderly transition from the ATDRSS to its follow-on (i.e. the DDSS CONUS Gateway architecture). The ATDRSS/FSG is a reserved allocation of spacecraft resources (weight, power, size, view angles) that will host a payload yet to be defined. The objective of the FSG is to support a modest growth in the services offered by ATDRSS. Possible payload options under consideration include a crosslink capability as well as a direct data distribution capability.

In Exhibit 6-3, timelines for three phased activities are shown to play a key role in support a smooth and orderly transition from ATDRSS to the CONUS Gateway architecture. These are as follows:

- Flight demonstrations of new capabilities and services via the ATDRSS/FSG
- Provision of new operational services via the FSG
- Launch of a demonstration satellite that will support existing ATDRSS satellites in a new mode to demonstrate and provide vastly improved services in concert with ATDRSS

The opportunities for the first flight demonstrations utilizing the ATDRSS/FSG will occur from the late 1990's to the early 2000's. If successful, similar payloads on the FSG will support service enhancements throughout the ATDRSS era, from the early 2000's to beyond 2010. Finally, starting about 2005, the launch of a demonstration satellite with similar capabilities to the DDS in the CONUS Gateway architecture would be feasible. Each of these activities are phased such that the preceding activity supports the definition of the follow-on. Thus, the POC models activity leads naturally into the detailed definition and development of FSG payloads. Similarly, successful demonstration of an FSG capability leads to operational support of that capability. This operational capability can then be greatly enhanced by the introduction of the demonstration DDS which in concert with a crosslink to the ATDRSS FSG, can close the ATDRSS coverage zone of exclusion and offer direct data distribution services. Finally, the demonstration DDS will support a gradual transition to the DDSS/ASDACS climax architecture as is shown in Exhibit 6-4.

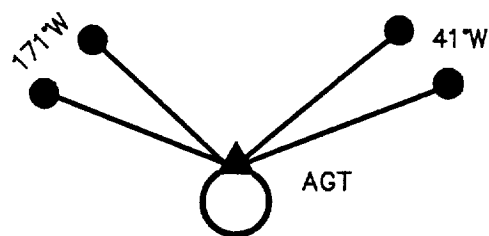




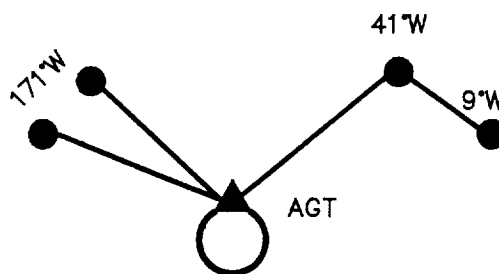
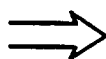
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Exhibit 6-3: Timeframes for Evolution from TDRSS to ATRSS and Beyond

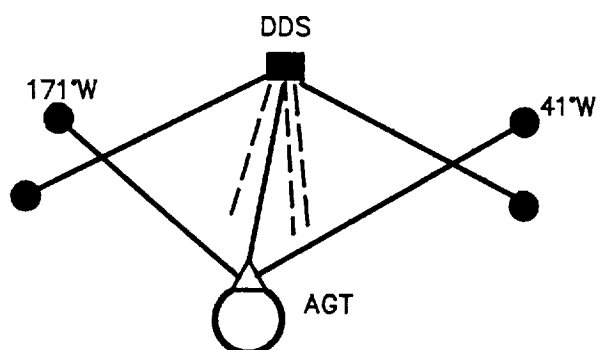
Exhibit 6-4 illustrates a potential scenario for demonstration and transition from the ATDRSS to the CONUS Gateway architecture. At the top is the baseline TDRSS architecture. In the FSG demonstration phase, just below, one of the eastern satellites at 41 deg. West would be moved to 9 deg. and be supported via a crosslink to the remaining ATDRSS satellite at 41 West. In this manner, the crosslink capability would be demonstrated along with closing the ZOE. Further down, with the introduction of the demonstration DDS, a hybrid architecture is established in which two of the satellites are supported directly via White Sands as in ATDRSS, and two satellites are supported via the DDS via crosslinks. This hybrid architecture provides a gradual transition phase since with a failure of either the DDS or ATDRSS baseline, half of the on-orbit service capacity is maintained.



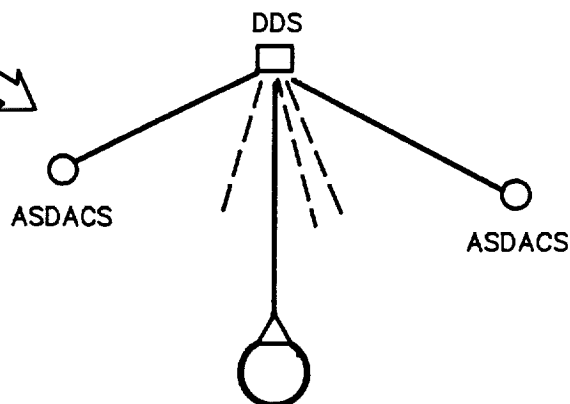
- BASELINE ATRSS ARCHITECTURE



- ATRSS/FSG DEMO
- EVOLUTION TO OPS
- SHORT X-LINK SUPPORTED BY FSG CLOSES ZOE
- LONGER X-LINK VALIDATES DEMONSTRATION DDS



- TRANSITION ARCHITECTURE
- DEMONSTRATION DDS DOES ON-BOARD PROCESSING AND PACKET SWITCHED DIRECT DISTRIBUTION OF DATA
- X-LINKS TO DDS SUPPORTED BY FSG CLOSES ZOE
- ALSO SUPPORTS NETWORKING AMONG MAJOR FACILITIES



- ASDACS HAS  $\geq 4$  SA CAPACITY AND X-LINKS TO DDS
- OPERATIONAL DDS DOES DIRECT DISTRIBUTION AND HAS INCREASED CAPACITY OVER DEMO DDSS
- DDS ALSO SUPPORTS SUBSTANTIAL NETWORKING LOAD AMONG MAJOR FACILITIES AND END USERS

#### KEY:

- ATRSS
- ASDACS
- DDS (DEMONSTRATION)
- DDS (OPERATIONAL)
- ▲ AGT
- △ AGT EVOLUTION

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Exhibit 6-4: Potential Route for ATRSS/FSG Evolution to ASDACS/FSG Conus Gateway Architecture

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## SECTION 7

### DEMONSTRATIONS AND PROOF-OF-CONCEPT MODELS

In this section, the key demonstrations and proof-of-concept (POC) models that support the development of the DDSS are identified and discussed.

## 7.1 OVERVIEW

Exhibit 7-1 summarizes four activities that are important for demonstrating the functionality and performance of key DDSS requirements. Each activity embodies a demonstration and an associated POC model development. The four activities are as follows:

- **Demonstration of Dynamic Multi-Access (DMA) Service:** The ATDRSS SMA array is used to demonstrate rapid beam steering and timed-shared use of a single SMA transmit beam by two or more Orbiting Platforms.
- **On-orbit Demodulation of Space-Space Channels:** The ATDRSS/FSG is used to host a payload that can demodulate all varieties of envisioned ATDRSS SMA services.
- **ATDRS-ATDRS Crosslink:** The FSG on two ATDRS are used to support an optical intersatellite connection supporting a data rate of 300 Mbps or more.
- **Extraction and routing of CCSDS virtual channel data units (VCDUs):** The FSG on an ATDRS is used to process a CCSDS data stream and extract at least two distinct VCDUs.

Each of these four activities is discussed below in greater detail. In addition, a payload with the combined capability of on-board demodulation, VCDU routing, and an optical communications terminal will have all the elements to demonstrate direct distribution of space data to selected locations.

DEMONSTRATION	KEY GOALS	KEY ELEMENTS	RELEVANT POC MODEL
TDMA Service Demonstration with ATDRS	<ul style="list-style-type: none"> <li>• TDMA Allocation of SMA FWD Beam to Multiple Users</li> <li>• Rapid Signal Acquisition</li> <li>• Rapid Hopping of SMA FWD Beam</li> </ul>	<ul style="list-style-type: none"> <li>• Orbiting Platforms W/Receiver Upgrade</li> <li>• ATDRS Beacon Service</li> <li>• ATDRS Enhanced SMA Phased Array</li> <li>• AGT Demand Access Interface</li> </ul>	TDMA Burst Receiver for Orbiting Platforms
On-orbit Demodulation of Space-Space Return Channels	<ul style="list-style-type: none"> <li>• Demonstrate a Workable Architecture Suitable for DDS Processing of all LDR/MDR ATDRS Return Channels</li> </ul>	<ul style="list-style-type: none"> <li>• ATDRSS/FSG Payload <ul style="list-style-type: none"> <li>– Flexible On-Board Demod for ATDRS Return Channels</li> </ul> </li> </ul>	Programmable RCVR for ATDRS Return Channels
ATDRS-ATDRS Crosslink	<ul style="list-style-type: none"> <li>• ZOE Closure Via Short Crosslink</li> </ul>	<ul style="list-style-type: none"> <li>• ATDRSS/FSG Payload <ul style="list-style-type: none"> <li>– Crosslink Optical Terminal on Two ATDRS</li> </ul> </li> <li>• Remote Contingency TT&amp;C GT</li> </ul>	Optical Crosslink Terminal for ATDRSS/FSG <ul style="list-style-type: none"> <li>• 300 Mbps Digital Links</li> <li>• 100 MHz Waveform Links via subcarrier Intensity Modulation</li> </ul>
Direct Data Distribution via an ATDRS	<ul style="list-style-type: none"> <li>• Strip CCSDS Packets From a 300 Mbps Data Stream and Route to Selected Destination</li> </ul>	<ul style="list-style-type: none"> <li>• ATDRSS/FSG Payload <ul style="list-style-type: none"> <li>– Routing of CCSDS Packets</li> <li>– Pace-to-Ground Link Antenna</li> </ul> </li> <li>• Ground Terminals <ul style="list-style-type: none"> <li>– Major Facilities</li> <li>– End Users</li> </ul> </li> </ul>	CCSDS Packet Processing for ATDRS/FSG <ul style="list-style-type: none"> <li>• 300 Mbps OR 150 Mbps Channel</li> </ul>

Exhibit 7-1: Key Demonstrations and POC Models

## 7.2 DMA FORWARD SERVICE DEMONSTRATION

Exhibit 7-1 illustrates a demonstration of multiple users sharing a single forward link beam of the SMA service of ATDRSS. This demonstration emulates the timeshared forward link DMA service defined in this study for the ASDACS. In order to carry out this demonstration, the following elements are required:

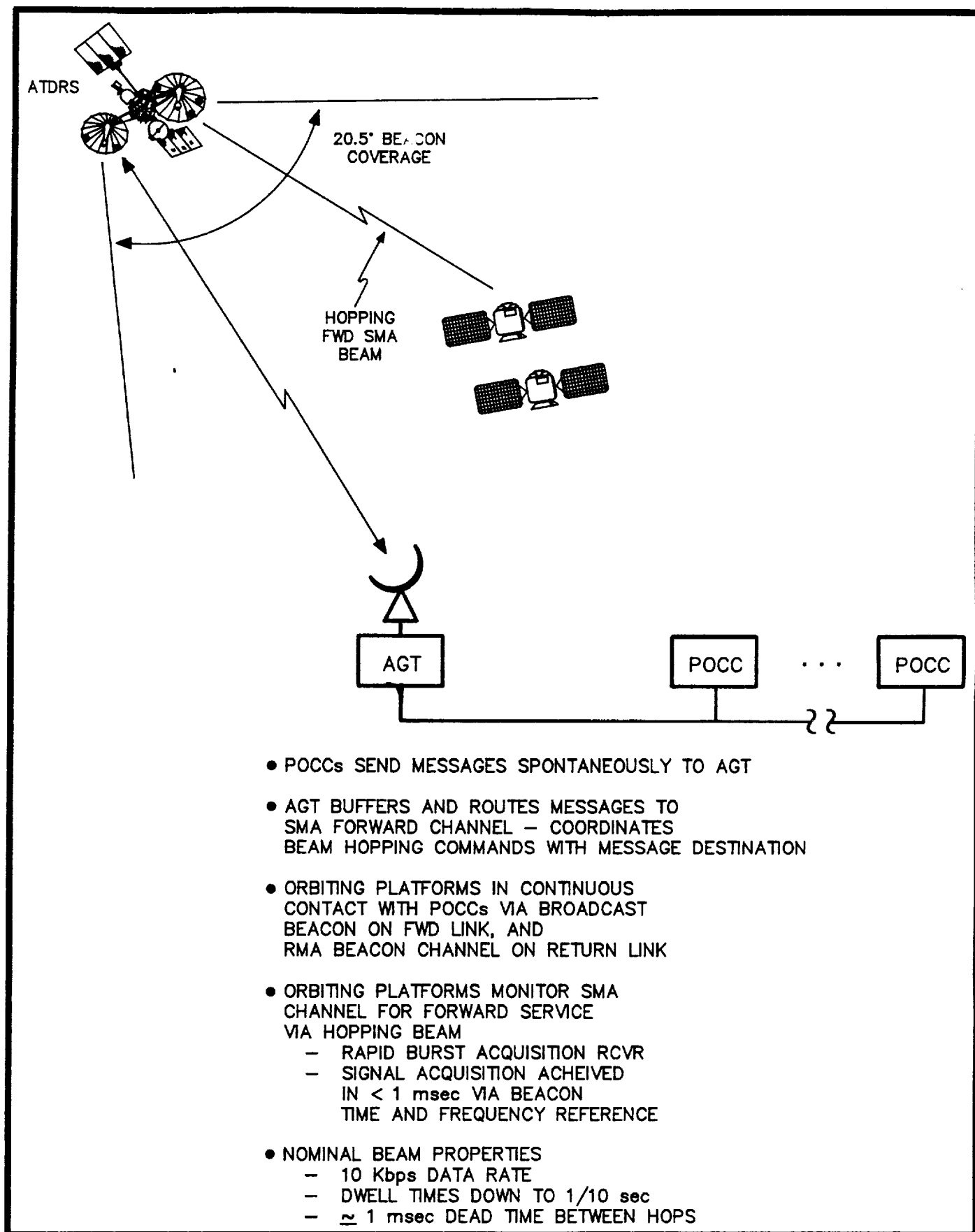
- The ATDRSS enhanced SMA array must be capable of rapid beam reconfiguration; a 1 msec reconfiguration time is a reasonable goal that can easily be met by current phased array implementations.
- The communications receiver of the Orbiting Platform must be capable of rapid signal acquisition; a 1 msec acquisition time of a forward beam can be easily accomplished if the receiver is already tracking the broadcast beacon which is coherently related to the forward beam.

If a 10 Kbps forward link is assumed, a tenth of a second dwell on a platform could transmit 1000 bits of data. If such a dwell is initiated every second, a 1000 Kbps link is established that is virtually continuous. Of course, to achieve this with a minimum of overhead, the forward beam must be rapidly configured, and the Orbiting Platform must rapidly acquire the frequency, phase, and bit timing of the signal. With such rapid reconfiguration and acquisition of the forward link beam, it can be effectively and efficiently shared.

Exhibit 7-1 outlines the concept and time sequence of events for the demonstration:

- The POCC, the ground controller for the Orbiting Platform, would spontaneously send blocks of messages and data spontaneous to the ATDRSS ground terminal (AGT).
- The AGT would buffer this incoming traffic and route this data stream to the channel of the SMA forward beam. The AGT would also control the SMA antenna beamforming to ensure that the beam is aimed at the correct Orbiting Platform.
- The Orbiting Platform user would always be in a beacon tracking mode and in a listening mode for a forward signal. Thus if the forward signal characteristics are coherently related to the beacon, the user can rapidly acquire the forward SMA beam.





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Exhibit 7-2: DMA Forward Service Demonstration Via ATDRSS

A key element of this demonstration is the development of a rapid acquisition user receiver. For the ATDRSS signal, the following conditions must be achieved for signal acquisition:

- Recovering and tracking PN spreading on both the I channel (short coded) and the Q channel (long code).
- Recovering frequency and phase of the RF carrier.
- Recovering the bit timing of the data stream.

Exhibit 7-3 illustrates a candidate architecture for a user POC receiver capable of such rapid acquisition of the ATDRSS SMA signal. The architecture is similar to that of the TDRSS Second Generation User Transponder built by Motorola [22], and to the TDRSS Balloon Transponder [23] and CCD Integrated Receiver [24], built by Stanford Telecom. In the POC receiver, the incoming signal at IF is divided into three paths, x, y and z. The x path is dedicated to the reception of the data channel (I) of the beacon signal: its PN correlator is matched to the beacon and in an ongoing manner, it performs PN code tracking, carrier tracking and data demodulation. The y path is dedicated to the range channel (Q) of the beacon. Its PN correlator is matched to the beacon range code. Together, the two beacon channels provide precise frequency and timing information to the user receivers. The z channel is dedicated to the reception of the SMA signal. On all three paths (x, y, and z) a frequency control word (FCW) input to the numerically controlled oscillator (NCO) determines the downmixing frequency. Since the beacon and the forward signal are coherent, the FCW of the forward link channel is simply a scaled version of the beacon FCW that adjusts for any frequency offset between the beacon and the forward SMA service beam. Thus, if the x and y channels are already tracking the beacon signal, the acquisition of the forward signal on the z channel can be very rapid since it starts from a state where all the signal characteristics except carrier phase are established by the x and y paths dedicated to the beacon.

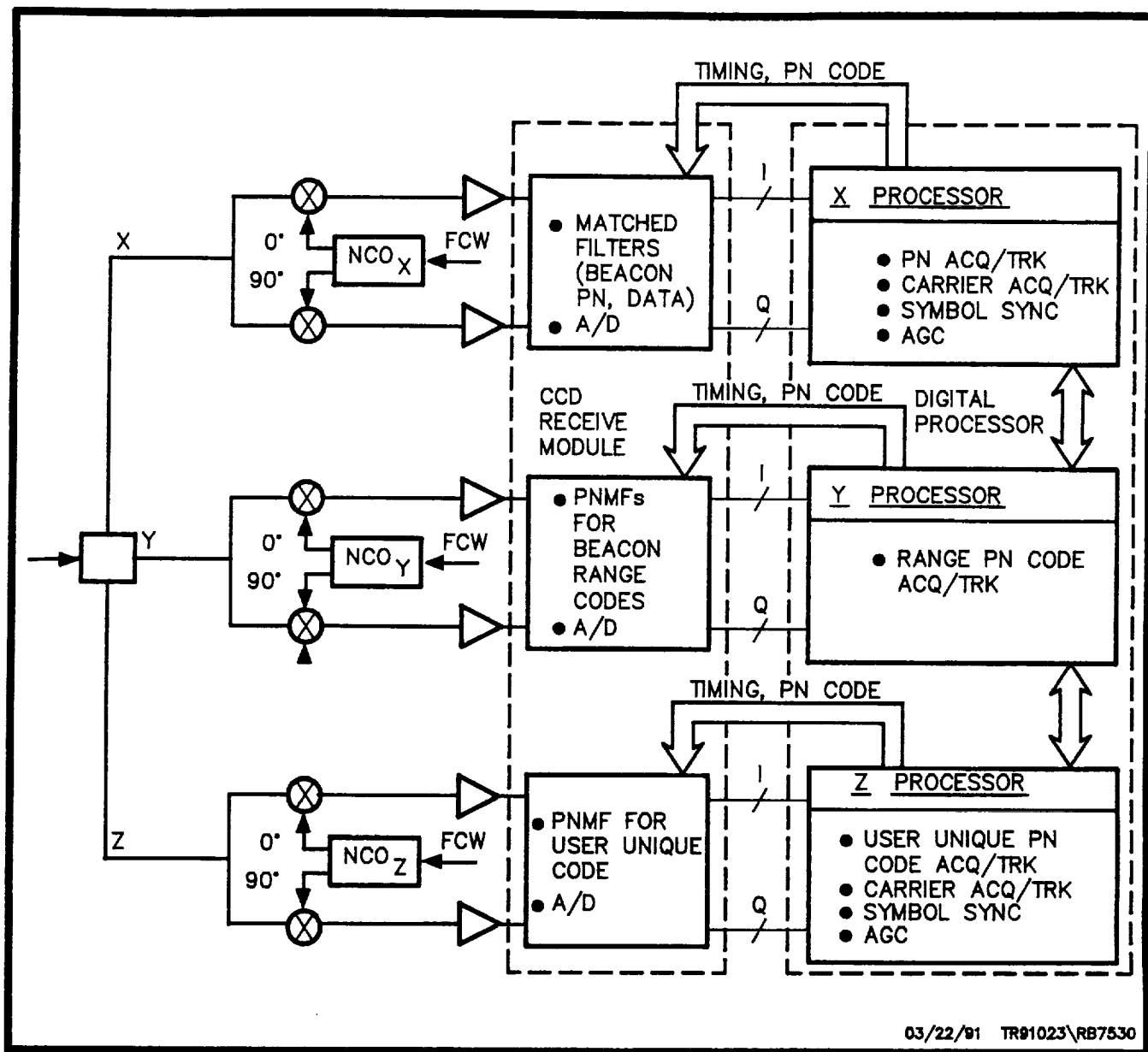


Exhibit 7-3: Candidate POC Model for Burst Receiver

### 7.3 ON-ORBIT DEMODULATION OF SPACE-SPACE CHANNELS

One of the prerequisites of the direct distribution of space data is on-board demodulation of the return link user channels. This is so because, typically, a data stream originating at a single source (i.e. Orbiting Platform), will contain many kinds of data sets with a different end destinations. Thus, if direct distribution of space data is to be implemented, the data streams from the Orbiting Platforms must be demodulated. Only in this way, can the data sets be read and routed in accordance with the information embedded in their headers.

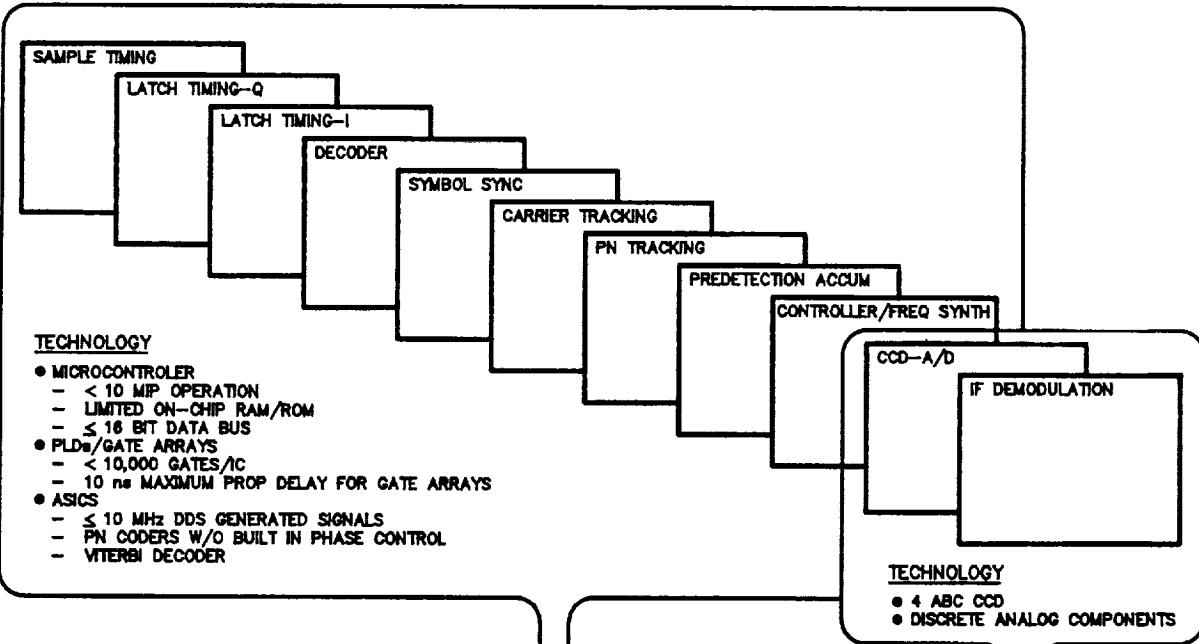
The current TDRSS, and the planned ATDRSS offer a flexible range of communications services to Orbiting Platforms including a continuous and wide range and data rates, and a wide variety of signal formats. In the initial TDRSS ground terminal at White Sands, NM, several distinct bit syncs and data demodulators were incorporated to support this variety. For an on-board demodulation implementation, it is clear that it will be important to build a flexible demodulator that can process the variety of data rates and formats that exists in the user community. The SMA return service in ATDRSS will likely support data rates from 100 bps to 3 Mbps and so a POC model demodulator that could handle this range of data rates and all applicable formats would be particularly valuable and relevant. Stanford Telecom has extensive experience in applying charge coupled device (CCD) technology to flexible demodulators. In fact, the output of a current project being done for NASA/GSFC is a single receiver implementation that can support all TDRSS return service modes below 10 Mbps [24]. Some of the highlights of this receiver include the following:

- CCD PN matched filter for fast parallel processing to achieve rapid PN phase acquisition
- FFT-based carrier acquisition
- Integrated tracking loop combining PN, carrier and bit sync tracking
- Programmable gate array (Xilinx) implementation of several receiver modules
- Advanced 2nd generation TI DSP chips for embedded microprocessors

Exhibit 7-4 illustrates the CCD integrated receiver demonstration hardware of the current project, and how it might evolve to satisfy requirements of a programmable on-board demodulator. The current CCD receiver embodies essentially all the functionality required of the POC model, but it is too large for this application: a single receiver has card count of 11. However, the general approach and algorithms of the current CCD receiver are applicable to the on-board application, and with the utilization of technology that will be available before 1995, it seems feasible to build a CCD based programmable receiver, with all the functionality required, utilizing only one digital card and one analog card.

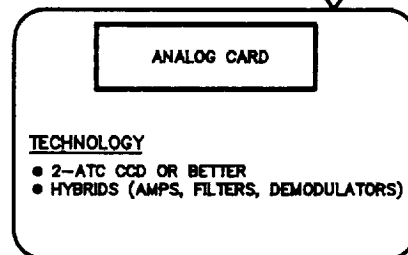
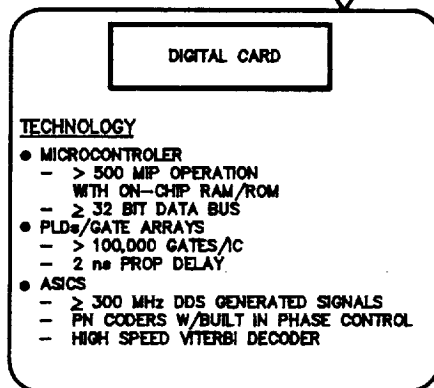
FUNCTIONALITY: TDRSS FORWARD AND RETURN  
LINK RECEIVER  $\leq 10$  MBPS,  
370 MHz IF INPUT

CARD COUNT: 11  
CARD SIZE: 14 X 14 in  
ENCLOSURE VOLUME: 8160 in<sup>3</sup>  
POWER REQUIREMENT:  $\sim 150$  W



FUNCTIONALITY: TDRSS RETURN  
LINK  $\leq 3$  MBPS, 370 MHz IF INPUT

CARD COUNT: 2  
CARD SIZE: 6 X 12 in  
ENCLOSURE VOLUME:  $< 300$  in<sup>3</sup>  
POWER REQUIREMENT:  $< 15$  W



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Exhibit 7-4: Charge-Coupled-Device Demonstration System

## 7.4 ATDRSS CROSSLINK DEMONSTRATION

The key elements of an ATDRSS crosslink demonstration are the ATDRSS/FSG for hosting the crosslink payload, and a crosslink payload that fits within the envelope envisioned for the FSG.

The current concept for the FSG incorporates the following envelope specifications:

- Maximum mass: 240 lbs.
- Maximum power & thermal: 260 watts.
- Maximum volume: 11 ft<sup>3</sup>.
- Field of view:  $\pm 77.5^\circ$  E-W,  $\pm 31.0^\circ$  N-S
- Interfaces with TT&C, frequency reference, RF signal, SGL downlink, electrical, thermal and structure.

Since the competition for real estate on the ATDRS is likely to be great, we have favored an optical implementation because it requires at most a 20 cm aperture. Furthermore, the technology of laser diode power sources is maturing rapidly so that reliable power of the magnitude required will be readily available. Some of the key features of the optical crosslink payload are as follows:

- A 20 cm telescope, two axis gimballed.
- About 100 mw of laser power per transmit channel, depending upon the GEO arc spanned.
- Three transmit and three receive channels.
- Two of the channels in each direction are digital high data rate channels matched to the ATDRSS highest data rate service and selected lower harmonics.
- One channel in each direction is a lower data rate analog waveform channel. This channel provides the flexibility of sending a number of low and moderate data rate services over a single channel while avoiding the need to demodulate the user channels. In this scheme, the RF waveform (that is a frequency division multiplex of the multiple channels) intensity modulates the laser transmitter.

Exhibit 7-5 illustrates the contents of the optical crosslink payload in logical schematic and 7-6 is a pictorial representation of the payload. A similar payload is being developed at this time by NASA/GSFC for their optical Flight System Development and Demonstration (FSDD) program [25].

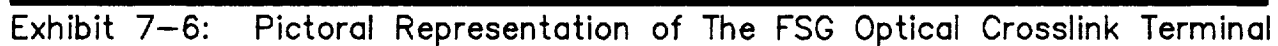


Exhibit 7-7 provides some of the key subsystem requirements as well as a breakdown of mass and power estimates by subsystem. The buses for these estimates include the FSDD [25], as well as a crosslink study just completed by Stanford Telecom for NASA/LcRC [26]. The crosslink payload described here is multi-purpose in that it can support a variety of demonstration activities. The most obvious one is a crosslink between two ATDRS. As discussed in Section 6, a short crosslink of only about 30° of GEO arc can close the TDRSS zone of exclusion. Some time later, this optical payload on the FSG can support the ATDRS interface with the demonstration DDSS in an early demonstration of the CONUS Gateway architecture. Here the crosslink would span about 80° of GEO arc.

Note that the estimated mass and power estimates are easily accommodated by FSG envelopes, thereby allowing the possible incorporation of onboard processing (demodulation - packet switching) into the optical terminal.



COMPONENT	DESCRIPTION	WEIGHT (LB)	POWER (W)
Telescope	<ul style="list-style-type: none"> <li>• 20 cm Diameter</li> <li>• <math>\lambda/10</math> Optics</li> </ul>	16	–
Gimbal and Drive	–	33	40
Optical Bench	<ul style="list-style-type: none"> <li>• <math>&lt; 1 \mu\text{rad}</math> Alignment Bias</li> <li>• <math>\lambda/30</math> Optics</li> </ul>	40	25
ACQ/TRK Subsystem	<ul style="list-style-type: none"> <li>• Sub <math>\mu\text{rad}</math> Tracking</li> <li>• 500 Hz Servo BW</li> </ul>	5	30
Laser Xmitters (3)	<ul style="list-style-type: none"> <li>• 1 Diode per Channel</li> <li>• 100 mW Per Diode</li> <li>• <math>\lambda</math>-DIV Channel MUX</li> </ul>	15	15
Laser Drivers/ Modulators (3)	<ul style="list-style-type: none"> <li>• Peak Current <math>&gt; 100 \text{ mA}</math></li> </ul>	18	15
APD/Preamps (3)	<ul style="list-style-type: none"> <li>• Gain <math>\approx 300</math></li> <li>• Low Noise</li> <li>• <math>\lambda</math>-DIV Channel Demux</li> </ul>	21	21
Demodulators (2)	<ul style="list-style-type: none"> <li>• Low Implementation Loss</li> </ul>	12	10
Total	–	160	156

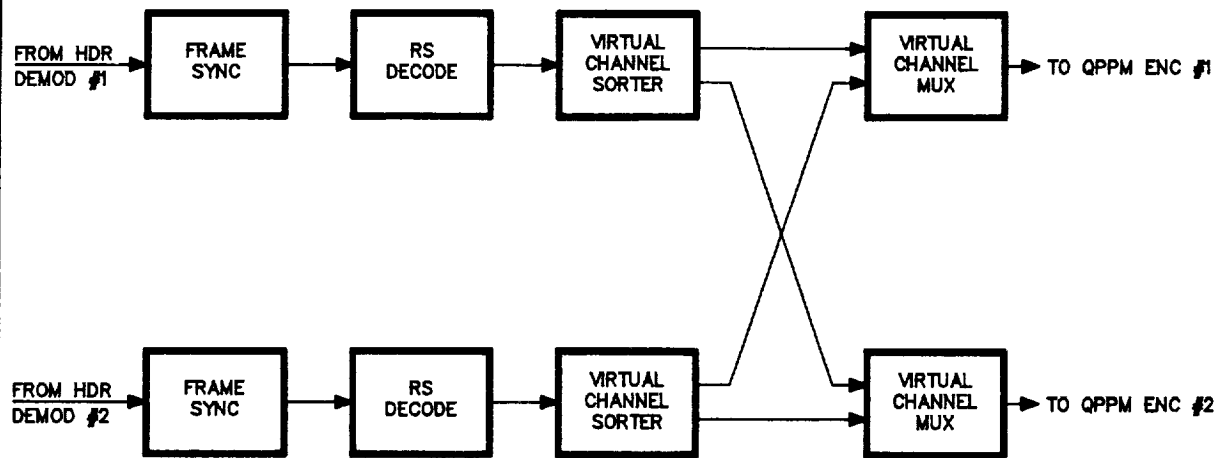
Exhibit 7-7: Description of Optical Crosslink Payload

## 7.5 EXTRACTION OF CCSDS VCDUs

In this section, the CCSDS packet processor for extraction and routing of virtual channels is discussed. Exhibit 7-8 illustrates a block diagram of an example CCSDS packet processor (developed by NASA/GSFC [19]) along with a list of component functions. For simplicity a limited processor is shown with two input data streams and two output data streams. The processing order of each input data stream is as follows:

- Frame synchronization.
- Reed-Solomon (RS) channel decoding.
- Virtual channel sorting.

The virtual channel sorting process divides the input stream into its component virtual channels. In the illustrated example, the sorters break up the input channels into two virtual channels. The virtual channel outputs are then routed to the virtual channel multiplexer. The virtual channel multiplexers combine the input virtual channel into a single output data stream. The resulting two output data streams may then be routed to different ground destinations.



- Each Box Supported By Single Card in Prototypes Developed By GSFC

- Frame Synchronizer Card
  - Identifies Frame Boundries
- Reed Solomon Card
  - Corrects Errors in CVCDVs
  - Header Parity Check and Correction
  - Determines Routability of CVCDVs
- VC Sorter Card
  - Routes VCDU to One of 2 Output Ports
  - Removes Fill VCDUs
- VC Mux Card
  - Multiplexes 2 Input Channels Into One Composite Output
  - Adds Fill VCDUs to Maintain Continuous Output

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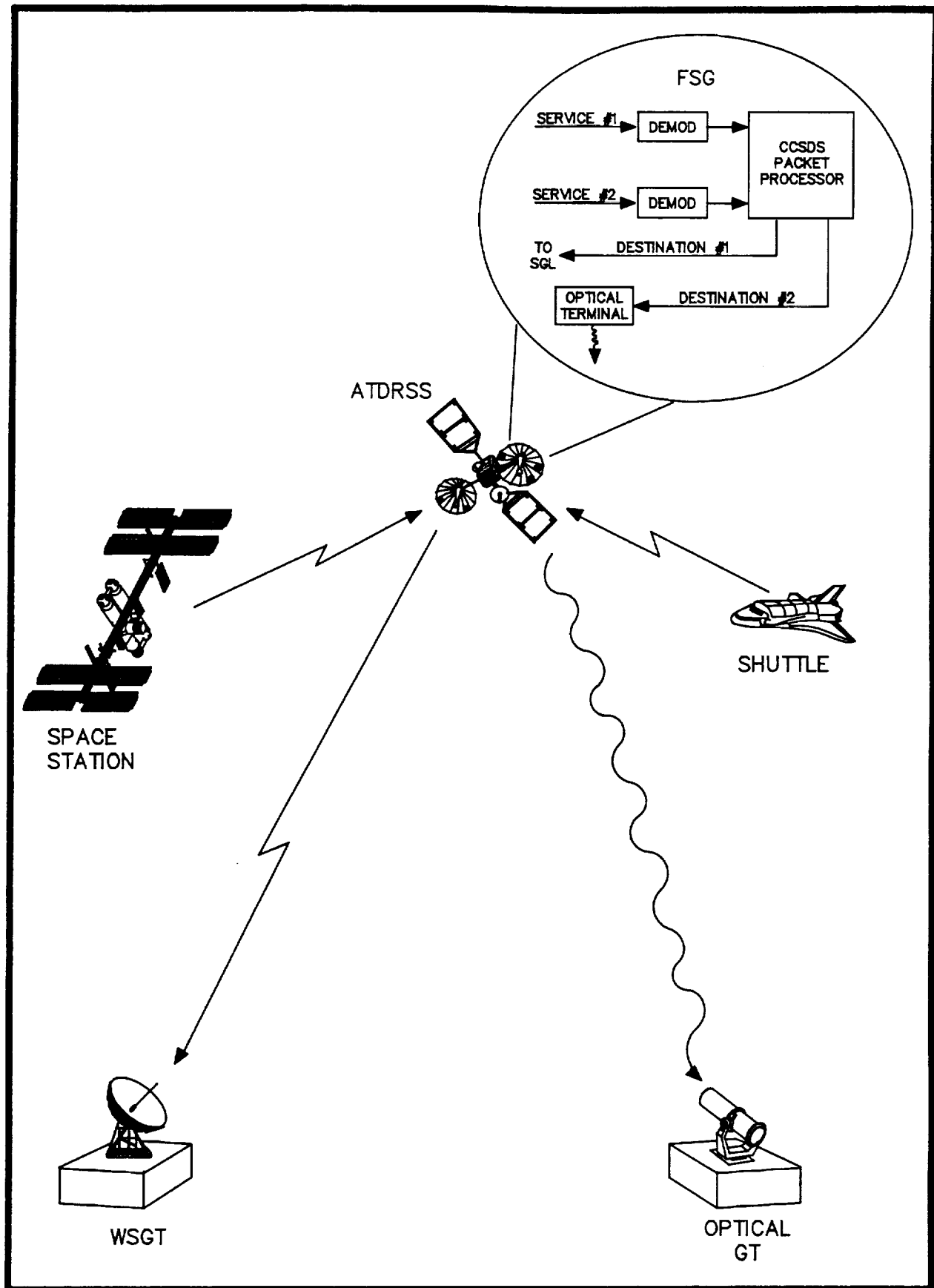
Exhibit 7-8: CCSDS Data Distribution Payload Description

## **7.6 DIRECT DISTRIBUTION OF SPACE DATA VIA THE ATDRSS/FSG**

If a space-space Orbiting Platform return link channel is to be flexibly routed in support of direct distribution of space data, the following elements must be in place on the ATDRSS/FSG:

- On-board demodulation of the channel.
- Multiple SGLs (to different locations).
- Packet processing capability to break up a CCSDS composite channel into its constituent virtual channels.

The POC model to accomplish the first item was discussed in Section 7.3. The optical terminal POC model, discussed in Section 7.4, can route data directly to an optical ground terminal with a cloud free line of sight. Finally, a CCSDS VCDU packet processor was discussed in Section 7.5. An FSG payload with all three can dramatically demonstrate direct distribution of space data as illustrated in Exhibit 7-9.



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Exhibit 7-9: Demonstration of Direct Distribution of Space Data

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## SECTION 8

### THE DEMONSTRATION DDS

This section describes the function and design of the demonstration Data Distribution Satellite in greater detail, and develops spacecraft mass, power and cost estimates.

## 8.1 CAPABILITIES

The primary rationale for the demonstration Data Distribution Satellite is to support the smooth transition to the climax CONUS Gateway architecture in the ATDRSS timeframe. With the proper payload on the ATDRSS/FSG to support the interface with the DDS, all the key operational capabilities of the climax CONUS Gateway architecture can be demonstrated and instituted in the ATDRSS timeframe. These capabilities include:

- Direct distribution of space data to Major Facilities and End User VSATs.
- Interactive operations of space payloads from VSATs.
- Wideband networking among all major facilities.
- Wideband access to Major Facilities from VSATs for data retrieval and supercomputer access.

Exhibit 8-1 summarizes the key drivers of the demonstration DDS payload and illustrates the various payload components. The envelope capacity for space data distribution is roughly 1.2 Gbps which is large enough to support at least one ultra-high data rate channel from each ATDRS. In addition, a networking capacity of up to 2 Gbps between Major Facilities is provided. The subsystems of the proposed demonstration DDS are follows:

- The SGL Subsystem: this contains a high gain transmitter, a high gain receiver, and a CONUS coverage receiver/transmitter.
  - The high gain transmitter implementation is a Ka-band phased array feed antenna with 8 hopping 0.3° beams that can scan all of CONUS. The power of each beam is between 2 and 20 watts, adaptive to rain degradation. The data rate supported by each beam is 300 Mbps to Major Facilities and 150 Mbps (rate 1/2 coded) to End User VSATs. Higher data rates to major facilities are supported via assignment of multiple beams.
  - The high gain receiver is also at Ka-band and supports ten fixed 0.3° beams distributed over CONUS so as to provide coverage to all Major Facilities. Each beam supports 300 Mbps.
  - The CONUS receiver/transmitter provides a shaped duplex beam at Ku-band covering all of CONUS. The transmit end supports a 1 Mbps TDM downlink for space data, and the receive end supports one or more 100 Kbps uplink random access channels.
- The Processing and Routing Subsystem: this includes a CCSDS processing capability for space data, and additional processing capability for the switching and routing of networking data.
- The Crosslink Subsystem: this includes the modems and codec for the ATDRSS space-space channels, and the two optical terminals that support the links to the two ATDRS.



### DEMONSTRATION DDS COMMUNICATIONS PAYLOAD DRIVERS

- Constraints: must be compatible with the crosslink interface of the ATDRSS/FSG - assume optical crosslink interface
- Objectives: validate and support ATDRSS transition/evolution toward the CONUS Gateway architecture
- Applicable timeframe: 2005 or shortly thereafter
- Target requirements:
  - Direct distribution of return space data
    - ♦  $\approx$  1.2 GBPS total capacity to Major Facilities
    - ♦  $\approx$  1 MBPS total capacity to End Users
    - ♦ on-board CCSDS packet processing & switching
  - Direct link for forward space data
    - ♦  $\approx$  100 MBPS capacity from Major Facilities
    - ♦  $\approx$  100 KBPS capacity from End Users
    - ♦ CCSDS packet processing & switching
  - Two crosslinks (up to 80° Geo arc) with ATDRSS/FSG
    - ♦  $\approx$  600 MBPS receive data rate
    - ♦ 100 MBPS transmit data rate
    - ♦ On-board modems/codecs for space-space channels
  - Networking of ground elements (e.g., Supercomputer highway)
    - ♦  $\approx$  2 GBPS total capacity between Major Facilities (300 MBPS links)
    - ♦ 150 MBPS links from Major Facilities to selected End Users.

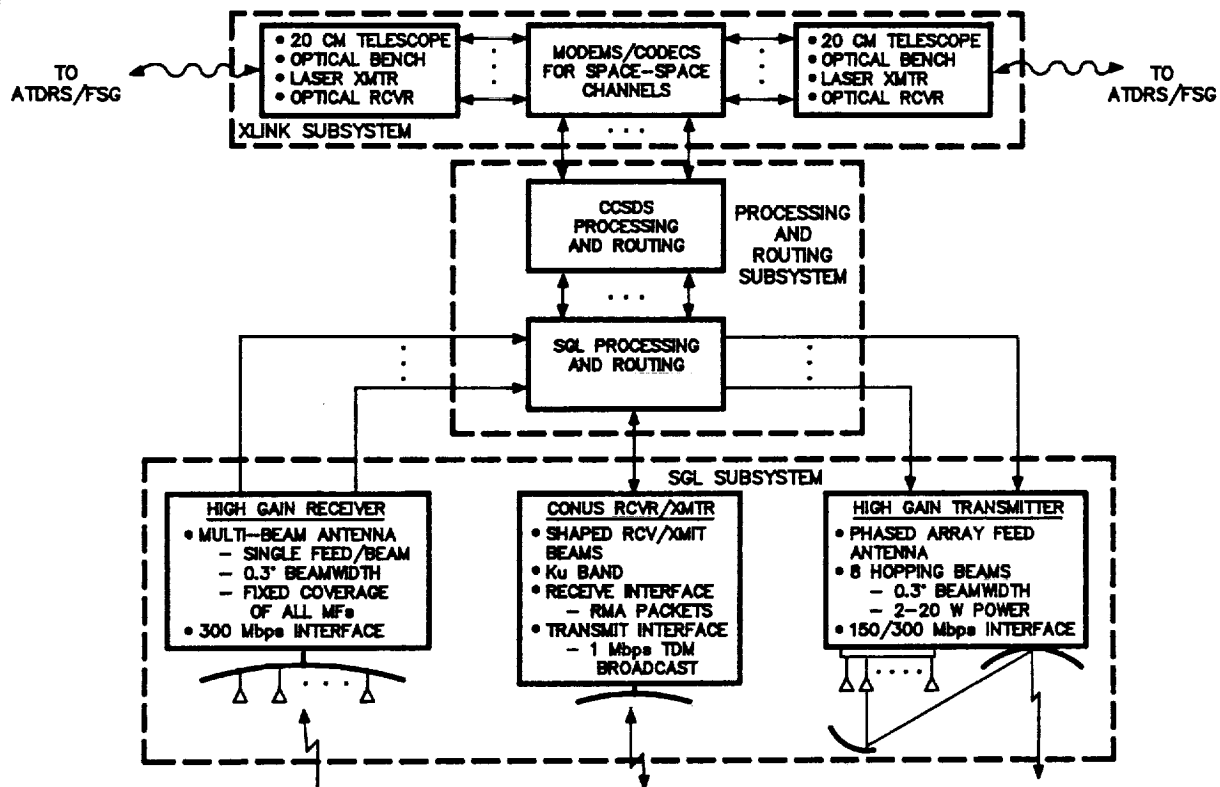


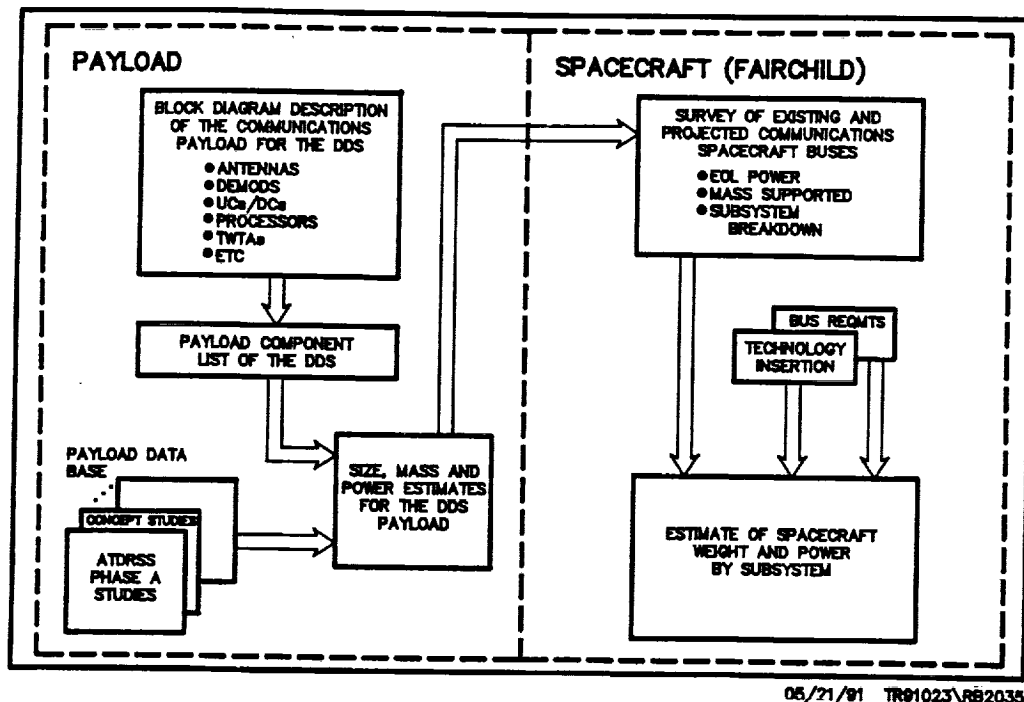
Exhibit 8-1: Demonstration DDS Communications Payload Drivers

## 8.2 PAYLOAD DESCRIPTION

Exhibit 8-2 contains a detailed payload diagram of the demonstration DDS. The major components are as follows:

- High gain receiver: 30 GHz
  - Multibeam antenna: 10 fixed beams @ 0.3°; 2.7 M diameter main reflector
  - 10 LNAs/DCs
  - 10 demod/decoders: 300 Mbps OR 150 Mbps (W/rate 1/2 coding option).
- High gain transmitter: 20 GHz
  - Multibeam antenna: 8 hopping beams @ 0.3°, 4 M diameter main reflector
  - Phased array feed radiator panel: 4 x 512 radiating elements
  - Active beamforming matrix
  - 8 modulator/encoders
  - 8 UCs/Preamps.
- Conus coverage Duplex transmitter/receiver: Ku-band
  - Conus XMIT/RCV antenna
  - Input frequency demux and down converter
  - Demodulator/decoders for the 100 Kbps RMA uplink channels
  - 1 modulator/encoder = 1 Mbps
  - 1 UC/HPA.
- Processing and routing subsystem
  - Packet processor/statistical multiplexer
  - Forward link virtual channel processor
  - Return link virtual channel processor
  - Dynamic crosspoint switch
  - Dynamic controller.
- Crosslink system
  - Frequency Mux/Demus and Modems/Codecs for space-space channels
  - 2 optical terminals: 20 cm apertures
    - ♦ 20 cm Gimbaled telescope
    - ♦ 3 APD/Preamps
    - ♦ 2 QPPM decoders
    - ♦ 1 100 mW laser.





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Exhibit 8-3: Methodology for P/L and Spacecraft Size, Weight and Power Estimation

### 8.3 PAYLOAD/SPACECRAFT MASS AND POWER ESTIMATES AND LAUNCH SCENARIO

Exhibit 8-3 illustrates the methodology for payload and spacecraft mass and power estimation used in this study. The table in Exhibit 8-4 summarizes the mass and power estimates for the communications payload of the demonstration DDS. The estimates were developed from the block diagram payload description in Exhibit 8-2. The sources of the data base used to generate the estimates (included in the table) encompass numerous payload studies for ATDRSS and several other studies of advanced communications payloads. The bottom line payload figures of 980 lbs. and 1669 watts are well within the envelope of currently considered payloads for communications satellites.

Exhibit 8-5 summarizes the satellite bus and launch alternatives for a payload of this size. In the GE series, the two bus choices are the 4000 and 5000. As indicated, the 4000 series bus is likely to be too small to support the DDS payload. The 5000 series bus can probably support a total mass of somewhat more than 6000 lbs. at liftoff and a total power of 3 KW at end of life. The mass envelope is roughly consistent with the following mass requirements for the spacecraft, stationkeeping fuel, and apogee kick motor (AKM):

- Spacecraft dry weight: 2584 lbs
- Stationkeeping fuel (10 years): 600 lbs
- AKM (partially loaded Thiokol Star 488-17): 3200 lbs

Thus the total weight estimate at liftoff is about 6500 lbs. This is clearly compatible with either an Atlas IIAS/Centaur launch or a Titan III launch. It is worth noting that it only slightly exceeds the launch capability for an Atlas IIA/Centaur.

SYSTEM ELEMENTS	WEIGHT (LBS)	POWER (WATTS)	BASIS OF ESTIMATE
HIGH GAIN RCV SGL	180	125	(18, 15)
HIGH GAIN XMIT SGL	272	738	(18, 15)
DUPLEX CONUS SGL	50	126	(18, 15)
SWITCHING AND ROUTING	80	360	(19, 21)
CROSSLINK TERMINALS	102 (X2)	90 (X2)	(16, 25)
PROCESSING OF SPACE-SPACE CHANNELS	112	140	(15)
TOTAL	980 (W/ $\approx$ 10% REDUNDANCY ALLOWANCE)	1669	-----

18. BALL AEROSPACE ANTENNA DEFINITION
15. ATRSS PHASE A STUDIES
16. ATRSS XLINK STUDY
25. GSFC OPTICAL FSDD
19. GSFC PROTOTYPING OF CCSDS PROCESSORS
20. TRW BULK DEMODULATION ESTIMATES
21. COMSAT PACKET SWITCHING STUDY

Exhibit 8-4: Summary Mass/Power Estimates for Demonstration DDS Payload

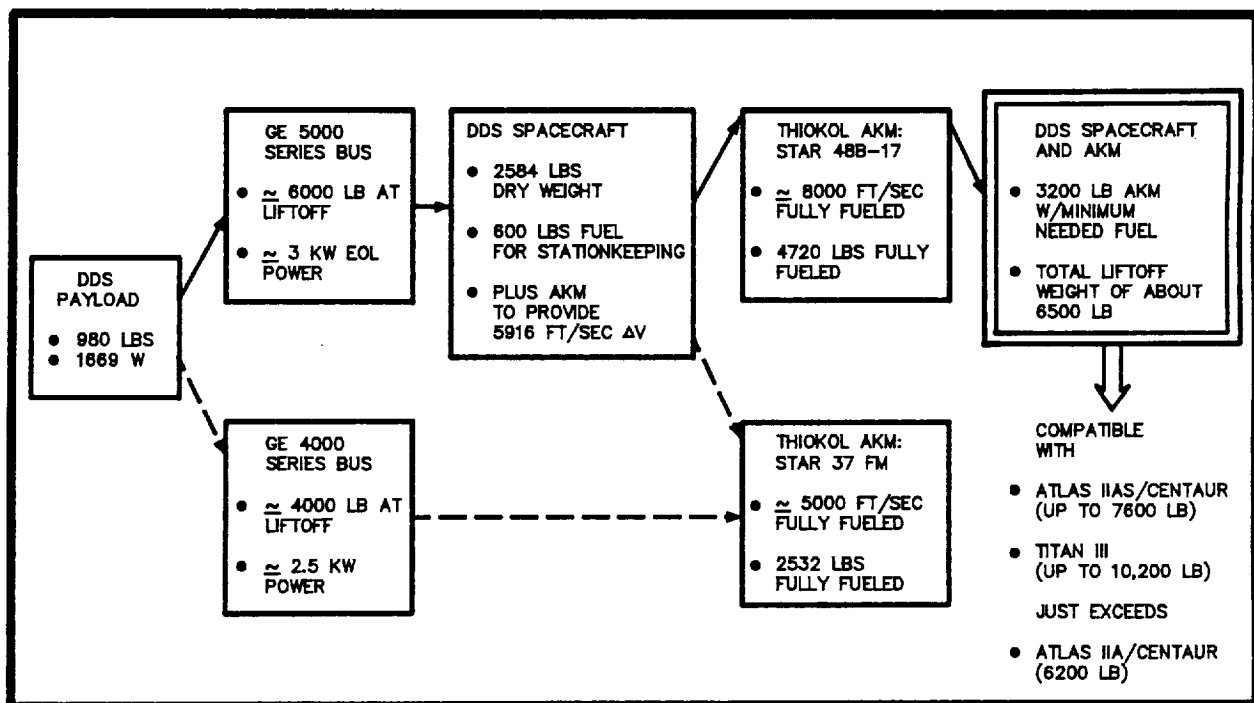


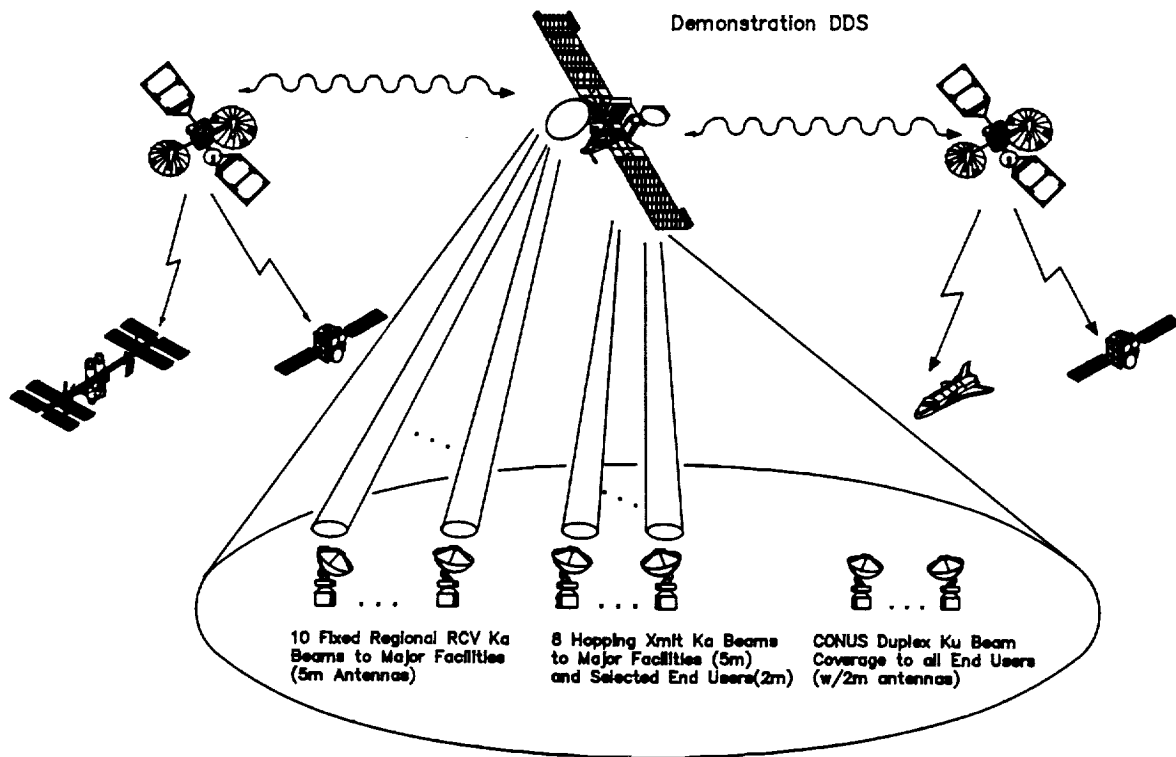
Exhibit 8-5: DDS Bus and Launch Alternatives 05/21/91 TR91023/RB7731

#### **8.4 SYSTEM ARCHITECTURE INCORPORATING A DEMONSTRATION DDS**

As discussed in Section 6, the demonstration DDS, in conjunction with ATDRSS constitute an interesting hybrid architecture in which one pair of ATDRS stationed at 41° and 171° West are supported directly via White Sands and a second pair are supported via the DDS. Exhibit 8-5 illustrates the segment of the system supported by the DDS. The system architecture and operations of the other two ATDRS are unchanged from the ATDRSS baseline. The DDS-supported ATDRS are provided flexible high data rate connectivity to many Major Facilities, and a 1 Mbps broadcast capability to 1000s of End User VSATs. Exhibit 8-5 also illustrates an artists concept of the DDS which clearly shows the transmit and receive multi-beam antennas, the optical crosslink terminals, and the CONUS coverage antenna.

## SYSTEM ARCHITECTURE INCORPORATING A DEMONSTRATION DDS

TWO OF FOUR ATDRS ARE CONNECTED TO GTs Via The DDS



## DATA DISTRIBUTION SATELLITE

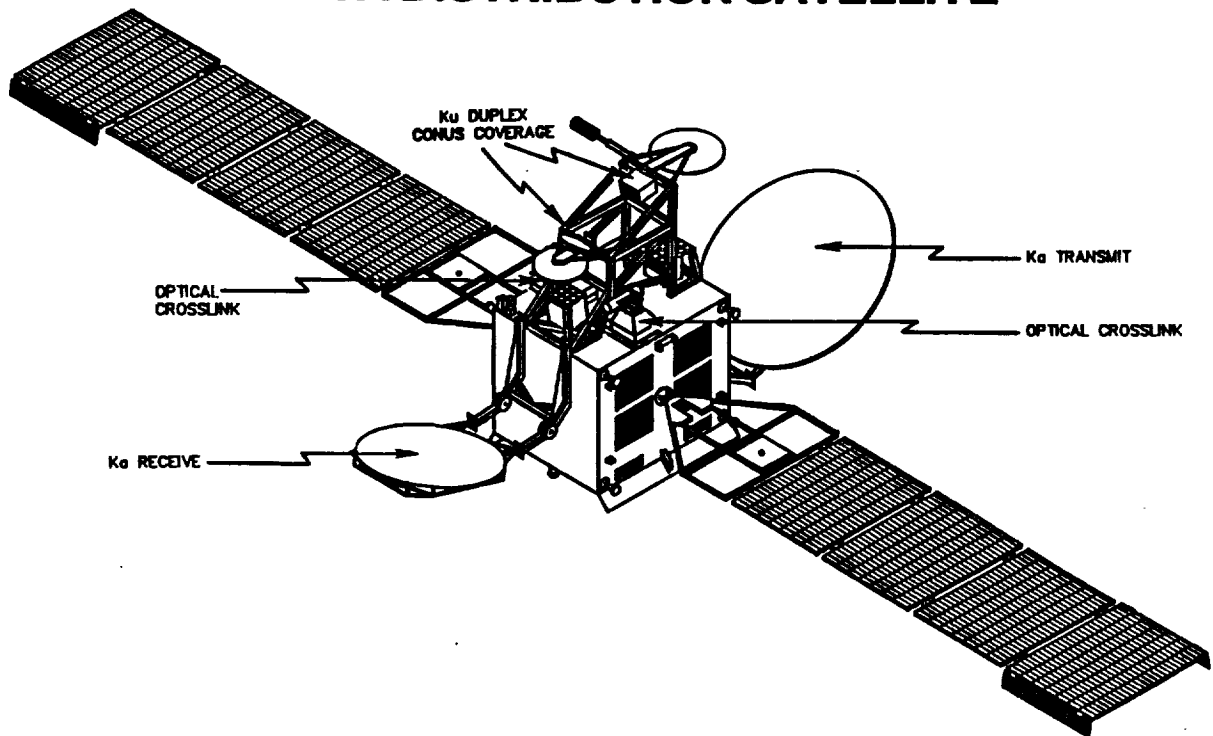


Exhibit 8-6: Demonstration DDS and System Architecture

## **8.5 COST ESTIMATES OF THE DEMONSTRATION DDS**

Exhibit 8-6 summarizes the cost estimates for the demonstration DDS. The payload and spacecraft bus costs were generated using the USCM6 cost model. The outputs are in 1986 dollars. The launch cost cited is based upon 1990 data and is in 1990 dollars. As expected, the cost of any new one-of-a-kind spacecraft is considerable. However, over half of the cost is attributed to non-recurring payload costs. If a significant technology development program is mounted throughout the 90's in support of DDS-like payload capabilities, the actual non-recurring cost is expected to be much less. Furthermore, any DDS program purchasing multiple copies will reap the significant unit cost reduction by spreading the non-recurring costs over the spacecraft copies. Learning curve phenomena will also promote cost reduction. The unit costs for 2 spacecraft and 10 spacecraft are tabulated in Exhibit 8-4 and are believed to represent reasonable upper and lower unit cost bounds. In summation, the cost of a demonstration DDS is expected to be in the range of 250 million to 500 million dollars.



- USCM6 COST MODEL (86\$)
- COST FOR BUY OF 1 S/C

ITEM	NON-RECURRING	RECURRING*	TOTAL
S/C	670 M\$ (~ 80% P/L) (~ 20% BUS)	240 M\$ (~ 70% P/L) (~ 30% BUS)	910 M\$
LAUNCH**	-	~ 100 M\$	~ 100 M\$

- SOME SUBSTANTIAL AMOUNT OF NON-RECURRING COSTS MAY BE SUBSIDIZED BY A FOCUSED TECHNOLOGY DEVELOPMENT PROGRAM
- A LARGE S/C BUY WILL SUBSTANTIALLY REDUCE S/C UNIT COSTS
- LOWER BOUND UNIT COST: 254.8 M\$
  - 10 S/C BUY
  - 80% LEARNING CURVE
- UPPER BOUND UNIT COST: 530.6 M\$
  - -2 S/C BUY
  - 80% LEARNING CURVE

Exhibit 8-7: Demonstration DDS Costs

---

\* INCLUDES AKM

\*\* ATLAS IIAS/CENTAUR OR TITAN III

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## Report Documentation Page

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16. Abstract  The Data Distribution Satellite (DDS) will be capable of providing the space research community with inexpensive and easy access to space payloads and space data. Furthermore, the DDS is shown to be a natural outgrowth of advances and evolution in both NASA's Space Network and commercial satellite communications. The roadmap and timescale for this evolution is described in this report along with key demonstrations, proof-of-concept models, and required technology development that will support the projected system evolution toward the DDS.					
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